Old Dominion University

Department of Civil and Environmental Engineering

AN EVALUATION OF THE EFFECTIVENESS OF A BEST MANAGEMENT PRACTICES (BMP) PLAN IMPLEMENTED AT AN OUTDOOR RIFLE RANGE

A Report in

Environmental Engineering

by

Robert Lyle Gersh

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Robert Lyle Gersh

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Master of Engineering

5 August 1997

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who is enrolled in the M.E. IN ENVIRONMENTAL ENGINEERING program, (title of degree program)

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Abstract

Lead contamination has been reported to be a problem at numerous military and civilian outdoor small arms ranges. Several best management practices (BMPs) have been suggested to reduce the leachability of the lead found in the soil. This paper evaluates the effectiveness of a particular BMP plan that was implemented during the Fall of 1996 at the Naval Amphibious Base (NAB) Little Creek, located in Norfolk and Virginia Beach, Virginia. NAB Little Creek's BMP implementation project included: (1) recovering bullets and bullet fragments from the soil for recycling, (2) tilling amendments (lime, phosphorus fertilizer, and leaf mulch) into the soil, and (3) planting vegetation (winter rye-grass) in the disturbed areas. Groundwater monitoring well samples drawn before and after the BMP implementation project were statistically analyzed using non-parametric tests to determine if the implemented BMP plan had any effect (positive, negative, or no effect) on the dissolved lead concentrations found in the groundwater. The findings confirm that after implementation of the BMP plan, the dissolved lead concentrations in the groundwater first went up in April 1997 then down in July 1997. A similar up-down trend in dissolved lead concentrations occurred in the groundwater samples drawn from the outdoor pistol range, even though no BMP project was performed there. Given the inconclusive nature of the findings, additional data collection and study is warranted to further evaluate the effectiveness of the small arms range BMP plan.

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Chapter 1
INTRODUCTION

1.1 Background

As of October of 1991, the U.S. Navy and Marine Corps controlled approximately 245 active and 56 inactive outdoor small arms ranges worldwide.[1] Due to the eventual build-up of bullets in the impact berms, it has been asserted that "these ranges are source areas for metals contamination."[2] Although copper and zinc have also been found at elevated levels at outdoor small arms ranges, lead is the most predominant and therefore remains the toxic metal of greatest concern.[3] This is due to the fact that lead is the primary component of most bullets, and is most likely to enter the environment through either physical means, such as soil erosion and sediment transport, or by geochemical means, such as precipitation/dissolution, adsorption/desorption, complexation/chelation, and oxidation/reduction.[4]

In the last eight years, Naval Amphibious Base (NAB) Little Creek has commissioned several studies of its outdoor rifle and pistol ranges to characterize the extent of lead contamination, if any, and to quantify the need for remediation (Baker & Weston, 1993[5]; Karr et al., 1990[6]; CH2M Hill, 1989[7]). These studies detected elevated levels of lead in soil and groundwater samples taken from both the outdoor rifle and pistol ranges. In 1995, NAB Little Creek hired Environmental & Turf Services, Inc. (ETS) of Wheaton, Maryland to develop a Best Management Practices (BMP) plan that would minimize the potential for future environmental impacts at its outdoor rifle and pistol ranges. In their March, 1996 report, ETS' BMP plan recommended, amongst other things, adding amendments (lime, phosphorus, and organic matter) to the soil of the pistol and rifle range impact berms and approaching aprons. ETS contended that lead was more likely to leach or run-off in soils that had low pH, little organic matter, low clay content, and low phosphorous content.[8] ETS also recommended establishing permanent (vegetative) cover at both ranges and surface run-off controls at the pistol range.[9]

In the Fall of 1996, the Navy hired OHM Remediation Services Corp. of Trenton, New Jersey to implement the BMP plan recommended by ETS at NAB Little Creek's outdoor rifle range. Due primarily to funding constraints, the outdoor pistol range was removed from the implementation project.

1.2 Objective

The main objective of this study was to evaluate the effectiveness of the BMP plan implemented by OHM at NAB Little Creek's outdoor rifle range. The effect (positive, negative, or no effect) of OHM's work on the dissolved lead levels found in the groundwater was determined by statistically analyzing groundwater monitoring well data taken from the site. A secondary objective was to make further recommendations to NAB Little Creek on its BMP plan for outdoor small arms ranges based on analysis of the results and a review of related literature.

1.3 Significance

Findings from this study could have implications throughout the Department of Defense. Simple, inexpensive, and effective BMPs that reduce or eliminate the potential environmental hazards posed by active and inactive outdoor small arms ranges would benefit bases which have such ranges. Currently, little guidance to minimize environmental impacts of active small arms ranges is available. Providing information to the Navy's small arms range policy makers so they can issue BMP guidance would remedy this situation. Since small arms range design is generally standardized, civilian owned and operated ranges could also benefit.

1.4 Site Description

The Naval Amphibious Base (NAB) Little Creek operates and maintains an outdoor rifle range and an outdoor pistol range. They are used by Navy, Army, and Marine Corps personnel to meet training and weapons qualification requirements. The ranges are operated five or six days per week.[10] The two ranges are located in Virginia Beach, Virginia, and are bounded on the

north by the Chesapeake Bay and on the south and southeast by Varian Lake, Lake Bradford, and Chub Lake. The direction of water flow is generally east to west from Chub Lake to Lake Bradford.[11] A site location map is shown in Figure 1.

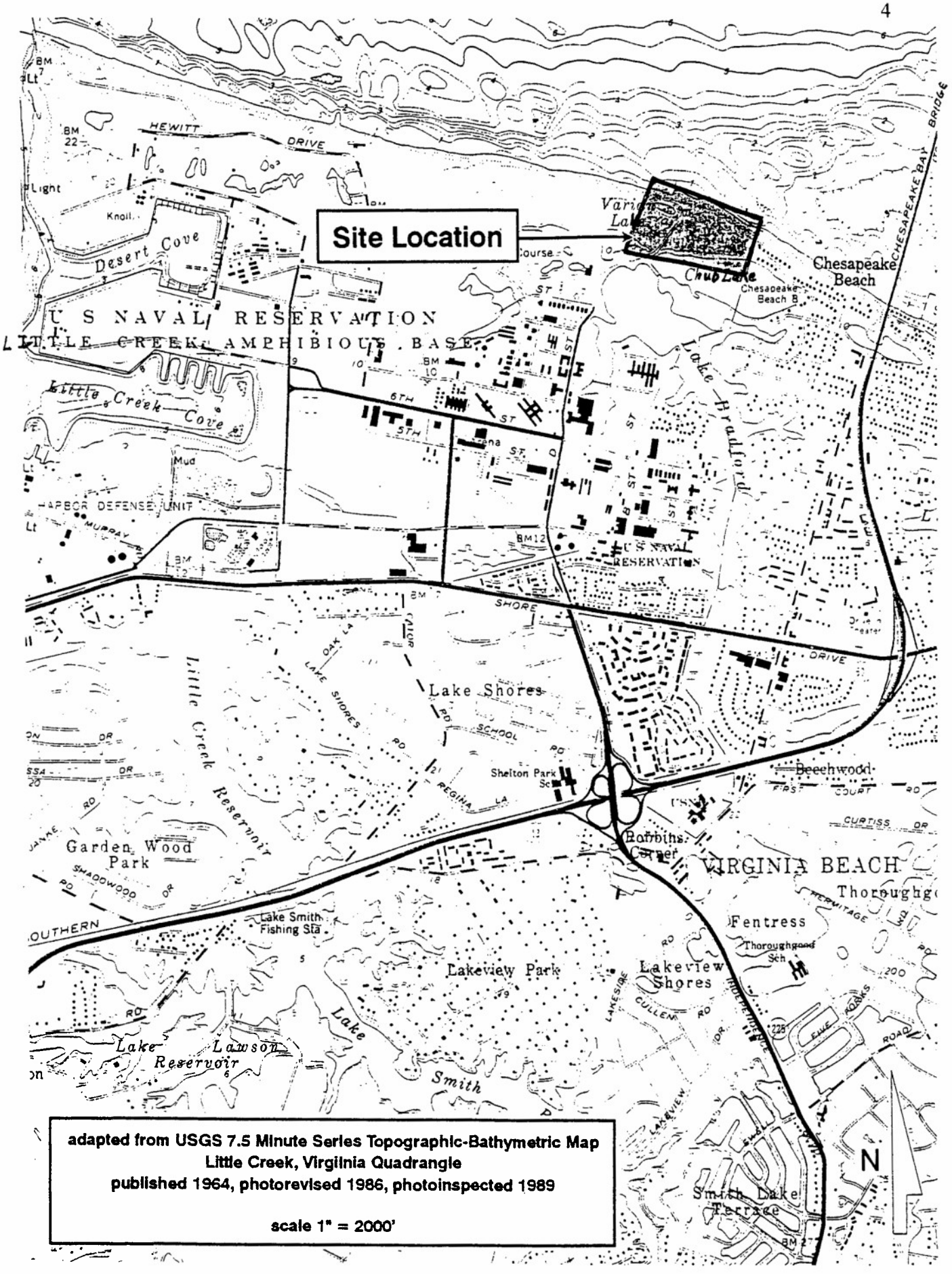

Figure 1: Naval Amphibious Base Little Creek Outdoor Small Arms Ranges Location Map[12]

Chapter 2
LITERATURE REVIEW

2.1 Lead in the Environment

Lead is a naturally occurring element in the environment. According to Davies and Wixson (1986), lead content in soil averages approximately 16 parts per million (ppm) with a normal range of 10 to 37 ppm.[13] Sittig (1980) found that lead levels in surface waters averaged approximately 3 ug/l (0.003 ppm) with a few streams exceeding 50 ug/l (0.05 ppm).[14] Similarly, Sittig (1980) found that groundwater lead levels that occur naturally were usually in the 1 to 10 ug/l (0.01 ppm) range, but may exceed 100 ug/l (0.1 ppm) in some areas of the country.[15]

Lead is also common in many man-made items such as in batteries, solder, radiation shielding, cable sheaths, and ammunition. Typical military ammunition such as bullets contain 90.0 to 99.2 percent lead and antimony according to military specification MIL-L-13283B of 19 August 1970.[16] The three main weapons (M14 and M16 rifles and the M60 machine gun) used at NAB Little Creek's outdoor rifle range fire metal jacketed bullets. The metal jacket of these bullets is primarily copper while their core is made of lead.[17]

The fate of lead in the environment is a complicated process. The Sporting Arms and Ammunition Manufacturers' Institute's (SAAMI) report on the subject (Lead Mobility at Shooting Ranges, SAAMI, 1996) explains that geochemical interactions, that are extremely complex, "are possibly the most important processes in understanding lead solubility and mobility in the environment."[18] The report explains that there are four important chemical processes "controlling lead fate and transport" in the environment:

(1) oxidation/reduction - the process responsible for converting metallic lead into more soluble forms, reduction being the opposite of oxidation.

(2) precipitation/dissolution - the process that removes lead from solution as a discrete solid form, dissolution being the opposite of precipitation.

(3) adsorption/desorption - the process through which naturally occurring mineral/organic [materials] remove lead from solution by binding them to their surfaces, desorption being the opposite of adsorption.

(4) complexation/chelation - the process where dissolved lead associates with other dissolved materials, resulting in higher dissolved lead levels.[19]

Further details regarding the fate of lead in the environment will be discussed later as it relates to the analysis of NAB Little Creek's BMP Implementation Project.

2.2 Dangers of Lead

Within the human body, lead in high enough concentrations is both toxic and a suspected carcinogen.[20] The third edition of Emergency Medicine states that "lead is the most common cause of chronic heavy metal poisoning and remains a major environmental contaminant."[21] Inorganic sources of lead, like lead bullets, adversely affect "the central and peripheral nervous systems, hematopoietic system, kidney, gastrointestinal tract, liver, myocardium, and reproductive capacity."[22] The American Water Works Association explains the human dangers of lead in somewhat more layman's terms:

> Health effects of lead are generally correlated with blood test levels. Infants and young children absorb ingested lead more readily than do older children and young adults. Lead exposure across a broad range of blood lead levels is associated with a continuum of patho-physiological effects, including interference with heme-synthesis necessary for formation of red blood cells, anemia, kidney damage, impaired reproductive function, interference with Vitamin D metabolism, impaired cognitive performance, delayed

neurological and physical development, and elevations in blood pressure. The US Environmental Protection Agency (EPA) has classified lead as a probable human carcinogen (group B2), because some lead compounds cause renal tumors in rats.[23]

Due to these potential health problems, EPA has set the Maximum Contaminant Level Goal (MCLG) for lead in drinking water at zero.[24] The EPA is required to determine safe levels of chemicals in drinking water by the Safe Drinking Water Act (SWDA) of 1974, Public Law 95-523. Although an MCLG is a non-enforceable goal, the EPA has set an enforceable Action Level for lead at 15 parts per billion (ppb),[25] which is equivalent to 15 ug/l. An EPA consumer fact sheet explains that since lead contamination in drinking water "generally occurs from corrosion of household lead pipes, it cannot be directly detected or removed by the water system. Instead, EPA is requiring water systems to control the corrosiveness of their water" if the level of lead at more than 10 percent of home tap water samples exceed the Action Level.[26]

NAB Little Creek's groundwater is not used as a source of drinking water. However, if the groundwater down-gradient from any outdoor small arms range was to be used for drinking, lead contamination could be a concern. Site specific groundwater testing should always be conducted in those cases.

2.3 Review of Best Management Plan (BMP) Recommendations

2.3.1 Recommendation No. 1: Periodic Recovery & Recycling of Bullets

2.3.1.1 Science Behind Recommendation

Periodically removing bullets and larger bullet fragments from the berm soil for recycling through sieving removes the source of lead contamination from the site. It also increases range safety by reducing the chances of ricochet.

2.3.1.2. Discussion

Removing larger bullet fragments from the berm soil initially seems to be a good idea, since it reduces a source of lead contamination and increases range safety. However, this recommendation is not without its problems. One problem is that the soil that passes through the sieve, and is often returned to the berm as it was at NAB Little Creek, could still be contaminated with minute particles of lead. Upon impact with the target or berm, a bullet can splatter into tiny particles that would pass through a sieve. Also, as the bullet passes through the upper layers of soil until its motion is stopped, lead from the bullet can smear onto adjacent soil particles, similar to chalk on a blackboard. Novstrup et al. reported that their bench scale testing on soil taken from a small arms range showed that physical separation techniques such as screening and gravity separation rarely were adequate by themselves to sufficiently reduce the lead content of the remaining soil. They explained that "chemical leaching processes are expected to be required to remove smeared and trapped lead in most cases".[27] Another problem is the depth of soil which is excavated and sieved. Although Barnes et. al. did not specify the depth of soil to be excavated in ETS' original BMP Plan, OHM's contract called for removing and sieving only the top six inches of soil from the berm. While this may be adequate for the lower velocity bullets found at a pistol range, most rifle bullets can be expected to penetrate deeper than six inches. Thus, much of the lead source material probably remained in the impact berm. A third problem deals with the screened particles retained by the sieve. When the first roll-off container of screened material (particles $\geq$0.25 inches) from NAB Little Creek's rifle range was shipped off to Exide/General Battery Corporation in Reading, Pennsylvania for recycling, it was discovered that the total lead content was only 1.14%.[28] Since this was too low a lead content for Exide to recycle, the Navy had to pay Exide to dispose of the debris as hazardous waste instead. This was because the lead concentration of the roll-off container's contents as determined by the EPA's Toxicity Characteristic Leaching Procedure (TCLP) test, which creates leachate from a representative sample, was 58.4 mg/L.[29] Under the Resource Conservation and Recovery Act (RCRA) of 1976, the EPA's TCLP regulatory level for lead is

5.0 mg/L.[30] Perhaps if the impact berm had been excavated to a greater depth, enough lead bullets might have been recovered to enable Exide to recycle the screened material.

2.3.2 Recommendation No. 2: Soil Amendments .

2.3.1.1 Science Behind Recommendation

There appears to be some scientific evidence supporting the theory that soil amendments can reduce the amount of dissolved lead leaving small arms ranges in the surface or ground waters. The EPA (1997) notes in a technical fact sheet that "lead is effectively removed from the water column to the sediment by adsorption to organic matter and clay minerals."[31] This lends credence to mixing organic material such as mulch into the soil. If the lead comes from the atmosphere, the EPA further states that it "will be retained in the upper 2-5 cm of soil, especially soils with at least 5% organic matter or a pH 5 or above".[32] Heath et al. (1991) supports this assessment when they state that "liming the target berms to increase pH and alkalinity may retard dissolution of lead into surface runoff and groundwater".[33] LaGrega, Buckingham, and Evans (1994) explain that "precipitation can occur when a chemical reaction transforms a solute to a much less soluble form, typically by mixing a precipitant with the solution (e.g., mixing of a lead solution with high carbonate waters can produce the relatively insoluble form $PbCO_3$[lead carbonate])".[34] EPA's technical fact sheet lists the solubility of lead carbonate at 0.0011g/L at 20° C and the corresponding solubility of lead phosphate as insoluble.[35] This would suggest that adding phosphorus to the soil could help precipitate lead out of solution in the form of lead phosphate.

2.3.2.2. Discussion

The soil amendments appear to make sense from a soil chemistry perspective. However, care must be exercised when applying amendments to the soil.

Barnes et. al. (1996) explain that the goal of adding lime is to raise soil pH in the top six inches to between 6.1 and 6.9.[36] It is therefore important that the ranges' soil pH be tested periodically to ensure that enough lime has been added to keep the soil in this range.

Unfortunately, OHM's contract did not specify testing the pH of the soil before, during, or after the 50 lb/1000 SF application of powdered lime to the top six inches of the soil. Therefore it is unknown how the lime additions impacted the soil pH.

Although the actual type of pellitized phosphorus fertilizer that was applied by OHM is unknown, if it was a standard agricultural fertilizer, it may also have contained significant quantities of nitrates. According to Mr. Robert Byrne of the Wildlife Management Institute, the addition of nitrates to the soil could enhance lead mobility because (1) lead nitrates are more soluble than lead phosphates, and (2) free nitrate could create an acidic condition which would increase lead mobility.[37] He cautions that the careful selection of fertilizer is therefore very important when adding phosphorus amendments to an outdoor arms range. In addition, phosphate itself also has the potential to adversely affect water quality and should be used sparingly.

While organic material has been shown in the laboratory to enhance chemical adsorption of lead, the kind of organic material added to the soil should be chosen carefully. If the organic material is acidic, it has the potential to neutralize the lime amendments that were intended to raise the soil pH. Unfortunately, the pH of the Navy supplied leaf and tree mulch that was applied by OHM is unknown.

2.3.3 Recommendation No. 3: Establishing and Maintaining Vegetation

2.3.3.1 Science Behind Recommendation

The BMP Plan's last recommendation for establishing and maintaining surface vegetation to reduce erosion and surface contamination is well supported. Karr et al. recommend that the impact berm be protected "from unnecessary erosion" to prevent surface contaminant migration.[38] Vegetation holds the soil in place with its root system while at the same time slowing the speed of incoming raindrops and surface runoff that would otherwise carry away suspended particles containing lead.

2.3.2.2. Discussion

While it may be difficult to establish vegetation in an area constantly impacted with high-velocity bullets, an alternative recommended by Novstrup et al. is to collect and treat surface water runoff with "a settling basin [on site] to remove lead particles and using either bioaccumulation or biofixation to remove dissolved lead prior to water discharge".[39] While such a detention basin may have a limited effect at NAB Little Creek due to its sandy and highly porous soils, it has the advantages of limiting site disturbances while removing lead particles and added phosphorus from the stormwater runoff.

Vegetation may have another benefit besides reducing soil erosion. In an article in the July 1997 issue of Smithsonian Magazine, John P. Wiley, Jr. describes an emerging remediation technology known as "phytoremediation, phyto being the Greek word for plant."[40] Like Novstrup et al.'s previous mention of bioaccumulation and biofixation, phytoremediation involves using specific plant species to draw soluble lead out of soil contaminated with heavy metals such as lead. The plants then must be harvested and disposed of as hazardous waste. Once criticism of phytoremediation is that it simply transfers the contamination problem to another medium. While this is true, planting, tending, and disposing of lead containing plants may still be less costly than conventional mechanical methods of remediation. Wiley even suggests that such plants could become a "cash crop: in the case of zinc and cadmium, the plants harvested from just one acre could be worth several hundred dollars."[41] While most of the phytoremediation schemes that Wiley suggests are still experimental, he does provide one example of its use in cleaning up lead contaminated soil.

> Suppose, for example, you have a piece of land that is saturated with lead. In normal soil, no plant will take up much of that lead. But if you amend the soil with a substance that will bind to the lead, the resulting compound will be taken up nicely by Indian Mustard (Brassica juncea). Environmental Science and Technology recently reported that on a New Jersey site where batteries once were made, the lead was nearly gone after one summer of this treatment.[42]

Although phytoremediation is relatively new and untested, early studies are promising.

2.4 Other Treatment Technologies

Other means of stabilizing the lead in small arms ranges have been demonstrated throughout the country. However, these methods tend to be significantly more costly and almost always involve proprietary processes. Two examples are:

2.4.1 Sieving and Soil Stabilization

A field demonstration using a stabilization process based on a soluble silicate and cement formulation was conducted at a small arms range at the Mayport Naval Air Station in Florida to evaluate the chemical effectiveness of this technology and to evaluate the ability to reuse the stabilized soil to capture bullets in the impact berm.[43] Approximately 170 cubic yards of soil was excavated from the face of the berm and passed through a 1/2 inch screen, which "proved satisfactory in sieving out most of the bullets".[44] The soil that passed through the sieve was subjected to a sodium silicate/Portland cement stabilization process, which consisted of 20% by weight of cement.[45] This process produced Toxicity Characteristic Leaching Procedure (TCLP) lead levels consistently below EPA's RCRA limit of 5.0 mg/L.[46] Since the TCLP levels of the untreated soil were well above 250 mg/l, the stabilization process significantly reduced the leachable lead content of the treated soil.[47] After curing, the treated soil mixture was spread thinly and broken up with front-end loaders. Despite concerns that the cement-stabilized soil would be unsuitable for reuse due to ricochet problems, the process instead yielded "a treated material that was relatively soft and friable, similar to the untreated berm sand."[48] The treated soil was therefore returned to the face of the berm, covered by a three- to four-inch layer of clean fill to prepare for revegetation, and finally hydromulched with a native grass. The cost of the project was $130,000 for approximately 170 cubic yards of soil.[49] That works out to be a cost of $764.7 per cubic yard of treated soil.

2.4.2 Chemical Fixation of Lead

Many commercially patented processes for chemical fixation of lead contaminated soils exist today. MARCOR Environmental recently utilized its three-part proprietary formulation Advanced Chemical Treatment (ACT) to successfully rehabilitate the outdoor small-arms firing range on Rodman's Neck Peninsula, Bronx, NY, which is used by approximately 30,000 police officers from the New York City Police Department and other jurisdictions.[50] MARCOR reported that prior to the treatment, "total lead concentrations exceeded 70,000 ppm, with leachable lead greater than 2,200 ppm---440 times the recognized hazardous level of 5 ppm [5 mg/L]".[51] MARCOR completely excavated the ranges side and impact berms to two feet below grade and trucked the soil to their on-site, multi-deck screening plant, where heavy fragments were extracted and sent to a local smelter for recycling. To improve the efficiency of separating the lead from the other screened debris, MARCOR invented a Pneumatic Separation Unit (PSU), which was used after the screening process to further segregate the lead from lighter rocks and debris. By using the PSU, MARCOR was able to recover and recycle 1.4 million pounds of lead, which at 10 cents per pound resulted in a $140,000 financial gain for their client. The entire cost of the project was $21 million, a small fraction of which was spent on site improvements besides soil remediation.[52] Since approximately 180,000 cubic yards of soil was treated, that works out to be $116.67 per cubic yard. Since the treated soil met the three clean-up criteria: (1) below 5 mg/l TCLP for lead, (2) pH levels suitable for vegetation regrowth, and (3) friable, soil-like consistency which enabled it to be reused in the berm without ricochet problems, the project was quite successful. After the treatment, all test samples "met or surpassed regulatory standards for TCLP as well as job-specific standards for the SPLP (Synthetic Precipitate Leachate Procedure); lead levels were frequently below detection".[53] MARCOR Environmental estimates it has chemically fixed the lead into molecules of pyromorphite that will remain stable, even in acidic environments, for "well over 500 years".[54]

Chapter 3
IMPLEMENTATION OF THE BMP PLAN

In October and November of 1996, OHM Remediation Services Corporation implemented portions of NAB Little Creek's Small Arms Range BMP Plan at its outdoor rifle range. Their work consisted of the following:

3.1 Soil Sieving

OHM excavated the top six inches of soil from the obvious impact areas of the rifle range berm and the approach apron to the berm as indicated in Figure 2. Areas on the backstop berm face with dense, established vegetation were excluded. Bullets and bullet fragments ≥0.25 inches in size were screened out of the soil using an industrial screening device. The soil that passed through the screens was returned to the rifle range as backfill. The screened debris was visually inspected. Any large clumps of soil or vegetation were removed from the screen, crushed, and put back through the screening device "to minimize the amount of non-bullet debris eventually containerized".[55] Remaining fragments which failed to pass through the screens were placed in two roll-off containers and shipped to Exide/General Battery Corporation in Reading, Pennsylvania for recycling. However, as explained earlier in section 2.3.1.2, the containerized material's total lead content was not high enough for Exide to accept for recycling. This unforeseen expenditure is one of the reasons the BMP Implementation Project was not performed on the outdoor pistol range, as had been originally planned.

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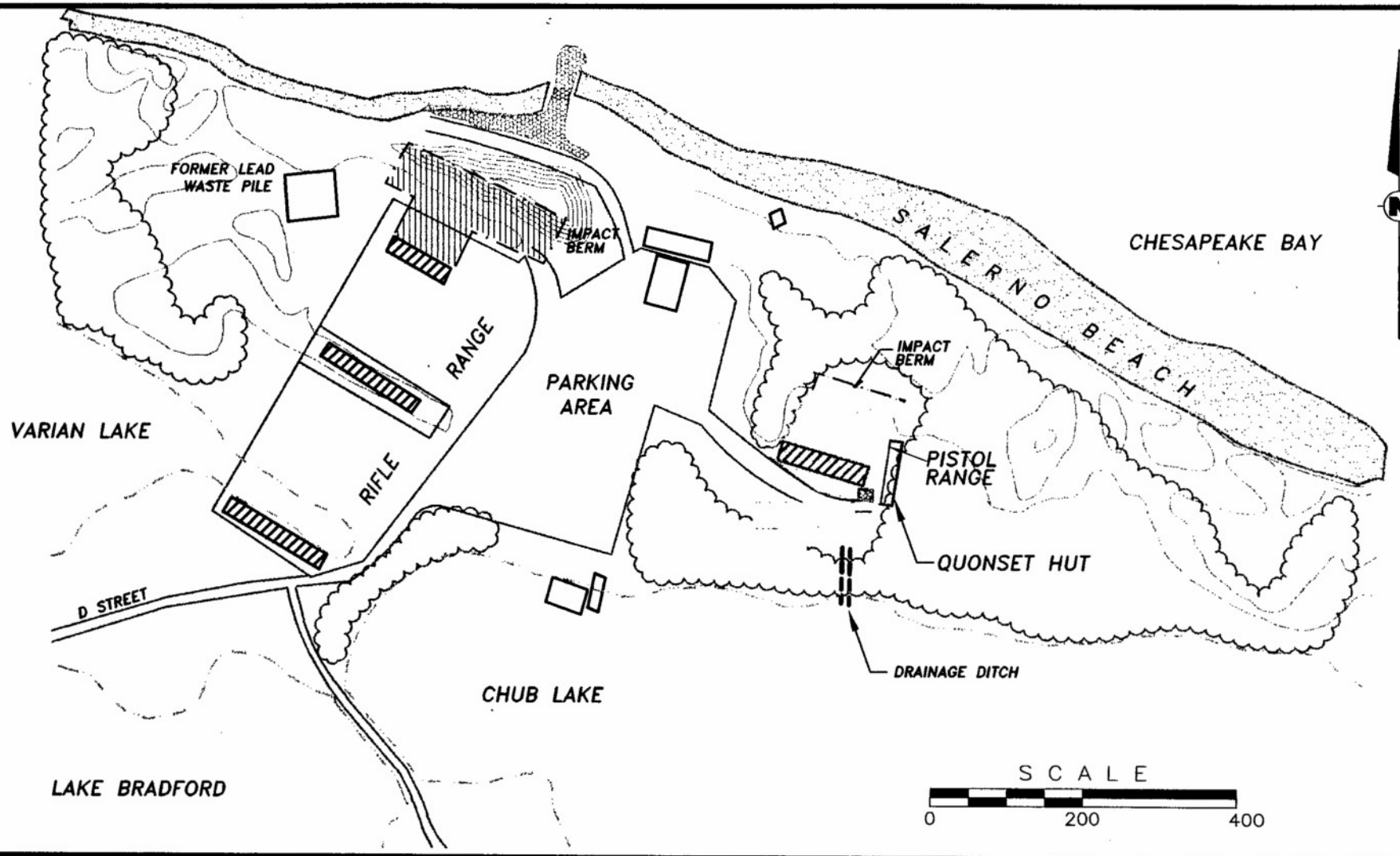


Legend

FIRING LINE

BULLET AND BULLET FRAGMENT REMOVAL AREA (INCLUDING SOIL AMENDMENT)

OHM Remediation Services Corp.

OHM Project No. 19099

Drawn By:	Checked By:	Approved By:
D. Leech	K. Lista	K. Lista
Date:	Scale:	Drawing No.
9/17/96	AS SHOWN	19099-A5

FIGURE 2

AREAS OF BULLET AND BULLET FRAGMENT REMOVAL AND ADDITIONS OF SOIL AMENDMENTS

PREPARED FOR

NAB LITTLE CREEK
VIRGINIA BEACH, VIRGINIA

Figure 2: Areas of Bullet and Bullet Fragment Removal and Additions of Soil Amendments

3.2 Soil Amendments

Using a power tiller, OHM mixed a number of amendments into the top six inches of soil in the same rifle range berm face and approach apron area which it had excavated and sieved, as shown in Figure 2. Powdered lime was applied at a rate of 50 lbs/1,000 ft^2. Pellitized phosphorus fertilizer was applied at a rate of 1 lb/1,000 ft^2, and organic matter consisting of Navy supplied leaf and tree mulch was applied at a rate of 150 ft^3/1,000 ft^2 (approximately 3 inches deep). The exact composition and pH of the leaf and tree mulch is unknown. Amendments were not mixed into the areas on the backstop berm face where dense vegetation was already established.[56]

3.3 Vegetation

The rifle range area disturbed by the sieving and soil amendments was seeded with winter rye-grass. Although the established rye-grass helped to reduce erosion over the winter, use of the range has again caused the soil to erode in the target area of the impact berm.

Chapter 4
POST-AUDIT OF BMP IMPLEMENTATION AND ITS DATA CHARACTERISTICS

4.1 Data Validation:

NAB Little Creek has collected groundwater monitoring well data since March 30, 1994. Nine sets of sample observations were performed by Environmental Testing Services, Inc. prior to the BMP plan implementation project, between March 30, 1994 and April 30, 1996. One additional set of sampling was performed by OHM Remediation Services Corp. during their project in October, 1996. To date, three sets of sample observations have been performed by Universal Laboratories after completion of the BMP plan implementation project, from January 17, 1997 to July 2, 1997. A summary of the raw groundwater monitoring well sample data collected through July 2, 1997 is in Appendix A.

Several issues related to the collected groundwater data had to be dealt with prior to performing any analysis.

First, different methods of measuring Total and Dissolved lead concentrations were used in the study data. In three instances, the laboratories used EPA Method SW-846 6010,[57] which uses Inductively Coupled Plasma (ICP) Emission Spectroscopy equipment. This test is not sufficient in detecting lead levels below 20 ug/L. The Method Detection Limit (MDL) for this test ranged from 14 ug/L to 50 ug/L. EPA method SW-846 200.7[58] is essentially the same as method 6010 with MDLs ranging from 16 ug/L to 18 ug/L. The third method used was EPA method SW-846 7421[59], which uses graphite furnace equipment to determine lead levels. According to Universal Laboratories, the method 7421, graphite furnace, is better at detecting levels at the low end (ppb) of the range scale than is either the methods 6010 or 200.7.[60] This can be seen from the MDLs for this test which range from 0.7 ug/L to 1.17 ug/L. Due to the unbalanced MDLs from different test methods, only the well data resulting from the more sensitive test method 7421 were included in the post-audit BMP analysis.

Second, there have been changes in the laboratories collecting and testing the well samples. The current lab performing the quarterly well sampling and testing is Universal Laboratories (UL). UL started collecting their first set of samples on January 17, 1997. The previous contractor, Environmental Testing Services, Inc. (ETSI) collected and tested their lasts set of well samples on April 30, 1996. Each lab has its own way of doing business, regardless of the method it uses to perform its tests. This is evident in the different MDLs the labs have for the same test method. Each lab performs a self-evaluation to determine the MDLs every 6-12 months. For example, Universal Laboratories' MDL for Total and Dissolved Lead using the graphite furnace Method 7421 is 0.7 ug/l. ESTI's MDL for the same testing method, on the other hand, varied from 1 ug/l to 1.17 ug/l. "Below Detectable Limits" in one lab may have been detected in another lab. However, the method 7421 MDLs for the two labs were comparable to minimize any concern.

Third, some of the data was removed from the data analysis due to their questionable accuracy. For example, the reported dissolved lead concentrations for wells GW-02, GW-07, GW-08, and GW-11 on September 29, 1994 were all higher than their corresponding total lead concentrations. According to Universal Laboratories, this is impossible since both measured lead concentrations (total and dissolved) are based on the same sample. The dissolved lead concentration is measured after the sample has been filtered through a 0.45 micron filter.[61] The data from September 29, 1994 was therefore excluded from analysis.

Lastly, other information collected from each groundwater sample was evaluated to determine if any of it correlated with the sample's dissolved lead concentration. This supplemental sample information, or factors, included field pH, specific conductivity, temperature, and hardness. The rational was that if such a correlation were found to exist, perhaps it could be used by range managers as a tool to monitor and/or reduce dissolved lead levels in the groundwater without expensive laboratory tests. Since the well samples drawn on April 30, 1996 were missing most of this information, it was also excluded from analysis.

4.2 Data Distribution

4.2.1 Data Summary

The four actively sampled wells at the rifle range are GW-02, GW-07, GW-08, and GW-11. Only the rifle range has implemented the recommended BMPs to date. Including the method 7421-based data and excluding the data from September 29, 1994 and April 30, 1996, as explained previously, three sets of data (March 22, 1995, June 16, 1995, and September 26, 1995) at 4 wells (a total of 12 data points) *before* the BMP implementation and two sets of data (April 21, 1997 and July 1, 1997) at 4 wells (a total of 8 data points) *after* the BMP implementation project were analyzed for this study.

A summary of the *before* and *after* data from the outdoor rifle range included in this analysis is shown in Table 1. The data for well GW-07 (March 22, 1995, September 26, 1995, and July 1, 1997) has been modified by substituting half of the corresponding MDL value in place of the reported non-detected value. This was done to prevent artificially skewing the data.

Table 1: Summary of data observations before and after the BMP implementation project.

CASE	Date	Lab	Dislvd Lead MDL (ug/L)	Well No.	Distance to Berm Face Center (ft)	pH	Field Specific Cond. (umhos/cm)	Field Temp (deg C)	Hardness (mg/L)	Disslved Lead Conc. (ug/L)	Relation to BMP Project
1	3/22/95	ETSI	1	2	300	4.43	50	14.6	28	51.00	before
2	6/16/95	ETSI	1	2	300	4.67	239	21.12	24	14.4.	before
3	9/26/95	ETSI	1.17	2	300	4.77	105	23.0	12	60.4.	before
4	3/22/95	ETSI	1	7	150	6.77	1700	13.9	530	0.5.	before
5	6/16/95	ETSI	1	7	150	6.20	20500	17.86	2040	4.38	before
6	9/26/95	ETSI	1.17	7	150	6.58	17500	23.0	1690	0.59	before
7	3/22/95	ETSI	1	8	90	5.40	60	19.9	44	87.00	before
8	6/16/95	ETSI	1	8	90	5.43	246	20.85	64	71.80	before
9	9/26/95	ETSI	1.17	8	90	5.80	197	22.0	60	116.00	before
10	3/22/95	ETSI	1	11	180	4.76	85	14.8	40	252.00	before
11	6/16/95	ETSI	1	11	180	5.29	194	20.32	48	64.20	before
12	9/26/95	ETSI	1.17	11	180	6.18	325	22.0	80	46.30	before
13	4/21/97	UL	0.7	2	300	4.80	60	14.9	9	39.80	after
14	4/21/97	UL	0.7	7	150	6.54	14200	14.2	2350	186.20	after
15	4/21/97	UL	0.7	8	90	5.36	63	15.0	25	207.20	after
16	4/21/97	UL	0.7	11	180	5.84	78	15.2	28	222.80	after
17	7/1/97	UL	0.7	2	300	4.45	45	22.4	10	0.90	after
18	7/1/97	UL	0.7	7	150	6.79	7000	20.7	1233	0.35	after
19	7/1/97	UL	0.7	8	90	5.36	75	21.2	20	13.40	after
20	7/1/97	UL	0.7	11	180	5.70	130	19.8	32	14.60	after

A frequency histogram of the dissolved lead concentrations, shown in Figure 3, clearly indicates the dissolved lead concentrations distribution does not follow a normal distribution. Given the small sample size ($n<30$), and the bimodality of the distribution shown in Figure 3, a non-normal distribution is assumed.

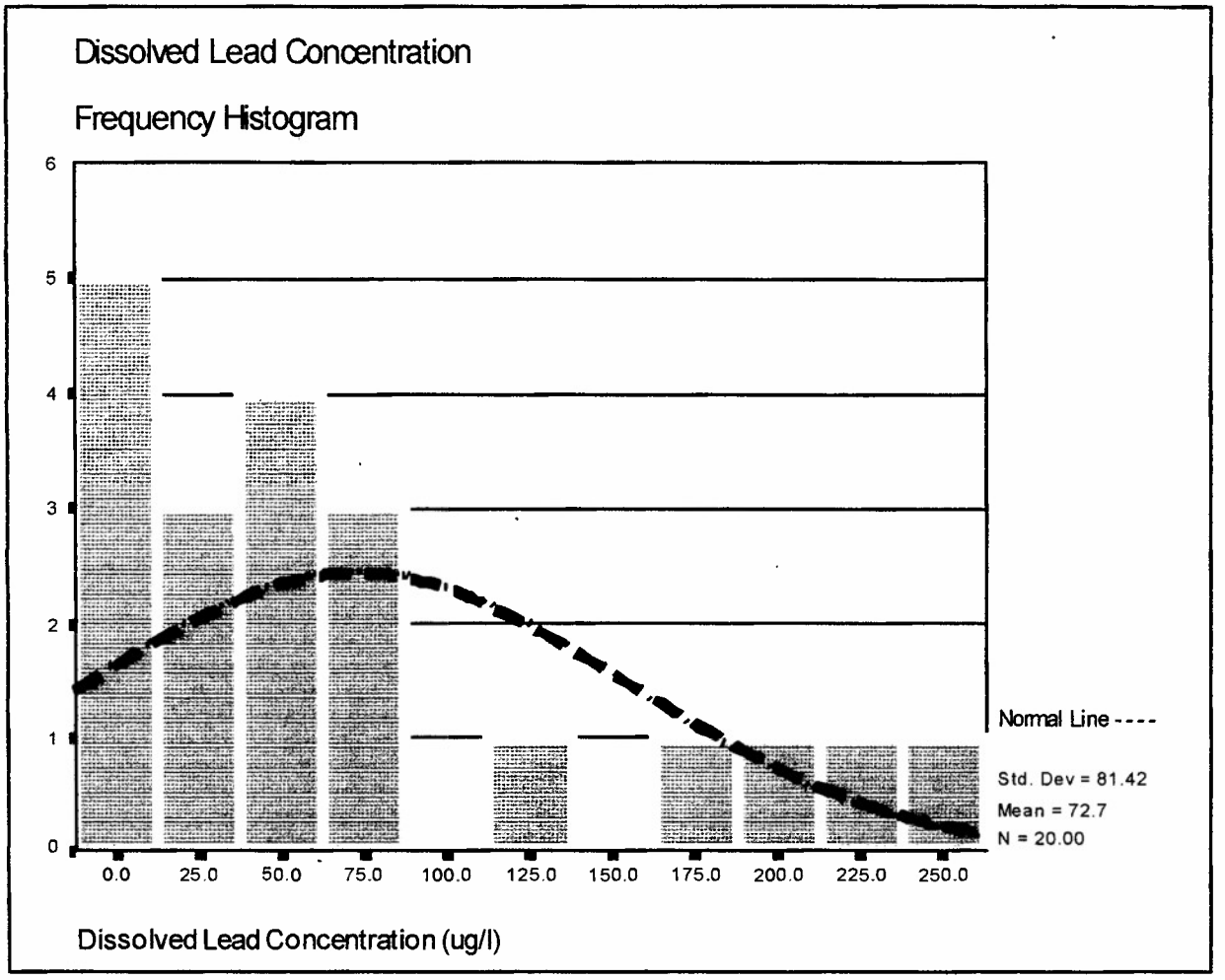


Figure 3: Frequency Histogram of Dissolved Lead Concentrations

4.2.2 Temporal Distribution

Due to the limited number of data points and their non-regular intervals, time series analysis could not be applied to this study.

4.2.3 Spatial Distribution

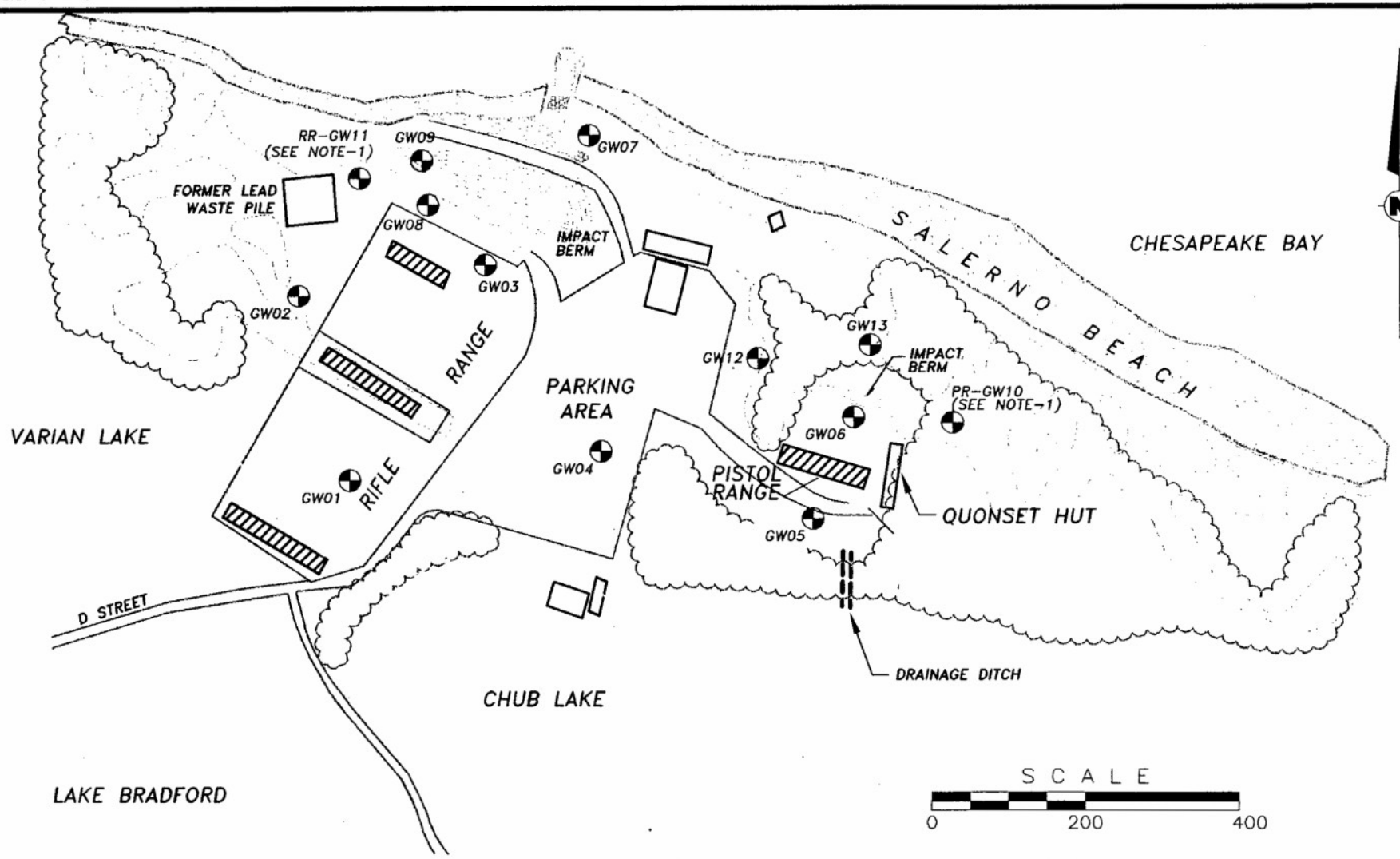
Figures 4 and 5 are site maps showing the locations of the groundwater monitoring wells. Well GW-08 was replaced with a new well a few feet from its original location during OHM's project in the Fall of 1996. Since the old and new well locations for GW-08 were essentially the same, the analysis proceeded as if there had been no change in well GW-08. Although only well GW-08 is located in the area of the rifle range that received soil amendments, the other sampled

wells, GW-02, GW-07, and GW-11, are distributed evenly around the rifle range. Scaled distances to the four wells from the center of the rifle range impact berm are shown below:

Well Number	Distance to Center of Impact Berm	Direction to Center of Impact Berm
GW-02	300 ft	NE
GW-07	150 ft	SW
GW-08	90 ft	NE
GW-11	180 ft	E

It should be noted that Figures 4 and 5 show the location of a former lead waste pile adjacent to well GW-11. According to NAB Little Creek sources,[62] this pile was created in September 1996 from soil contaminated with lead that had been removed from the faces of the rifle and pistol range impact berms. It measured approximately 73 ft x 82 ft x 3 ft deep. NAB Little Creek was issued an enforcement order by the Virginia Department of Waste Management in September 1989 to remove the pile and remediate the location. Subsequently, the pile was removed and the site cleaned up to a depth of 8-9 ft during the period from 23 March to 5 April, 1995. Except for the set of samples drawn on 22 March 1995, all remaining well samples were drawn after the pile was removed. Since this pile essentially existed before any samples were taken, any lasting effects from it would have been essentially the same in both before and after samples. As a result, this former pile's affect, if any, has been ignored in the analysis.

Plot Scale: 1 = 1 revision 0 CAD File: 19099-A2



Legend

MONITORING WELL

FIRING LINE

1) ALL RIFLE RANGE SAMPLE LOCATIONS DENOTED BY RR.
ALL PISTOL RANGE SAMPLE LOCATIONS ARE DENOTED BY PR.

OHM Remediation Services Corp.
OHM Project No. 19099

Drawn By:	Checked By:	Approved By:
D. Leech	K. Lista	K. Lista
Date:	Scale:	Drawing No.
9/17/96	AS SHOWN	19099-A2

FIGURE 4

GROUNDWATER MONITORING
WELL LOCATION MAP

PREPARED FOR

NAB LITTLE CREEK
VIRGINIA BEACH, VIRGINIA

Figure 4: Groundwater Monitoring Well Location Map

Figure 5: Groundwater Monitoring Well Survey

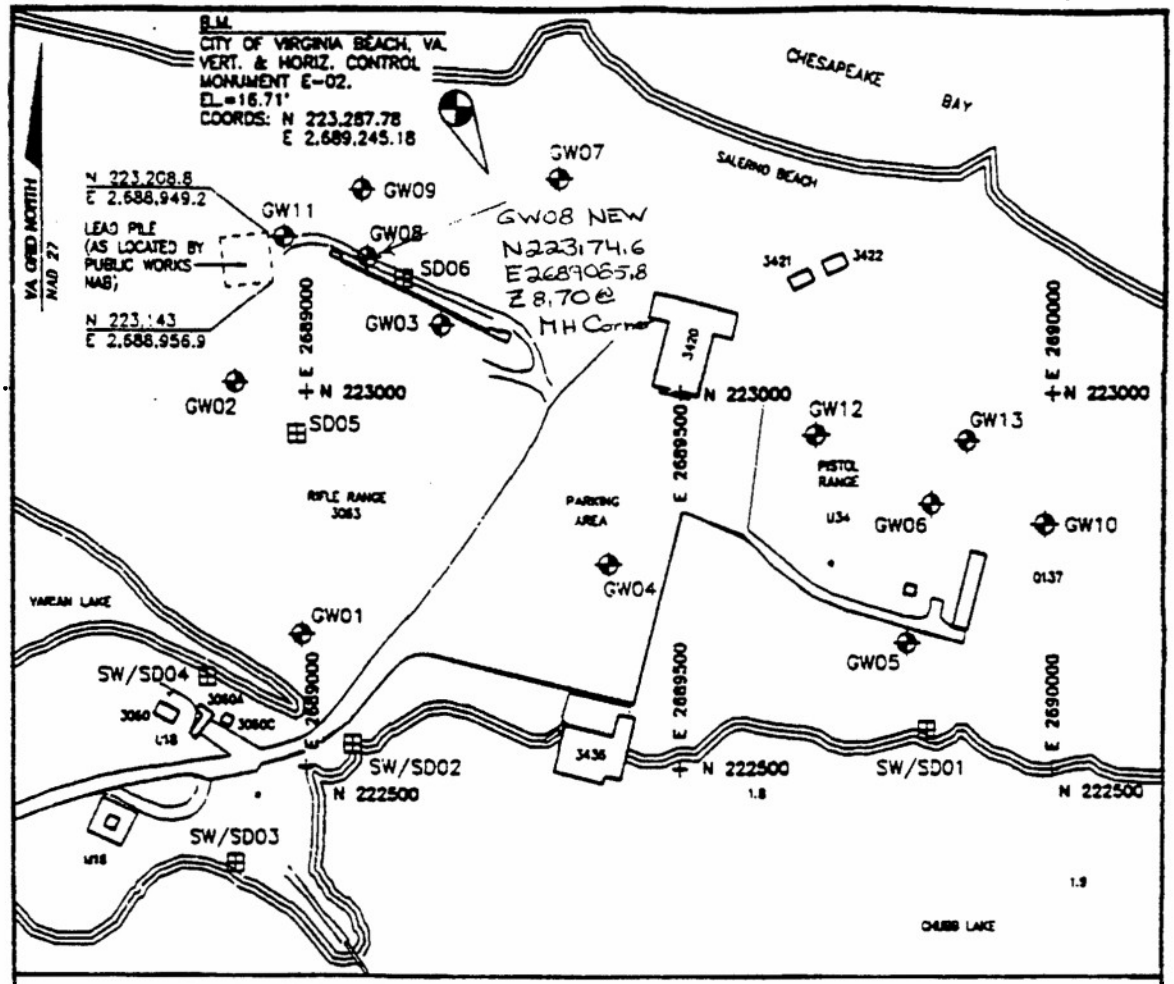
SOURCE:
Site Characterization
'stol Range and
.fle Range
Naval Amphibious Base
Little Creek
Virginia Beach, VA

Contract Task Order
0135
Contract
N62470-89-D-4814

Prepared By:
Baker Environmental, Inc.
Coraopolis, PA

and

Roy F. Weston, Inc.
West Chester, PA
August 1993
(APPENDIX D)



BORING NUMBER	EXIST. GROUND ELEVATION	NORTH COORD. (FT.)	EAST COORD. (FT.)
SW/SD01	5.7	222,551.1	2,689,829.3
SW/SD02	5.6	222,530.9	2,689,062.3
SW/SD03	5.8	222,370.8	2,688,905.1
SW/SD04	4.4	222,619.7	2,688,865.5
SD05	4.7	222,945.4	2,688,987.9
SD06	7.8	223,148.7	2,689,131.2
SS07	8.5	223,081.8	2,689,192.0

NOTES:

COORDINATES SHOWN ARE REFERENCED TO VIRGINIA STATE PLANE COORDINATE SYSTEM, SOUTH ZONE, NAD 27.

ELEVATIONS SHOWN ARE IN FEET AND ARE REFERENCED TO VIRGINIA BEACH VERTICAL DATUM (NGVD 29).

WELL NUMBER	RIM ELEVATION	TOP OF CASING ELEV.	EXIST. GROUND ELEVATION	NORTH COORD. (FT.)	EAST COORD. (FT.)
GW01	7.23	7.07	6.9	222,677.2	2,688,994.2
GW02	8.62	8.32	8.6	223,012.2	2,688,904.2
GW03	12.91	12.40	12.8	223,088.4	2,689,182.0
GW04	7.69	7.09	7.72	222,774.4	2,689,404.3
GW05	10.24	9.70	6.9	222,666.8	2,689,800.9
GW06	9.61	9.40	9.5	222,852.2	2,689,834.9
GW07	14.23	14.04	11.9	223,281.3	2,689,338.4
GW08	9.46	9.15	9.3	223,177.9	2,689,082.3
GW09	12.96	12.63	12.2	223,267.8	2,689,074.4
GW10	14.14	13.58	10.3	222,826.9	2,689,989.9
GW11	10.22	9.81	10.2	223,204.0	2,688,970.9
GW12	13.47	13.08	10.6	222,944.3	2,689,678.8
GW13	6.68	6.59	5.8	222,937.4	2,689,885.4

Updated 11/6/96

WELL LOCATION

SEDIMENT/STREAM WATER SAMPLE

F.B. 347, PG. 1
2 AUGUST 1993

SCALE: 1" = 200'

200 0 200 400

scale feet

SOIL BORING AND
MONITORING WELL LOCATION SURVEY
NAVAL AMPHIBIOUS BASE
LITTLE CREEK

VIRGINIA BEACH, VIRGINIA

HOGGARD/EURE ASSOCIATES
Surveyors/Planners/Engineers
Portsmouth, Virginia 23703

PROJ. NO.: 768 13-83

4.3 Groundwater Sampling and Testing Procedures

4.3.1 Sampling Procedure

The groundwater monitoring wells at NAB Little Creek are sampled according to the following procedures.[63]

(1) At each well, the well casing cover is opened and the cap unsealed.

(2) The length from the top of the well casing to the top of the water level is recorded as "Depth to Water Level" (DWL).

(3) The length from the top of the well casing to the bottom of the well is recorded as the "Total Well Depth" (TWD).

(4) The difference between the total well depth and depth to water level yields the well's "Water Column Length" (WCL).

(5) The volume of the water column in the well in gallons is calculated (well diameter is two inches). Three times the water column volume equals the well's "Purge Volume".

(6) A Teflon bailer is used to remove the Purge Volume of water from each well. The purpose of this purge is to make sure all of the stagnant water in the well has been removed prior to sampling. The purge water is stored on the Naval base until the lab results reveal whether or not the water will need to be disposed of as hazardous waste.

(7) After rinsing the bailer with distilled water, the actual water sample from the well is taken. Care was exercised not to touch the bottom of the well to avoid stirring up any sediment that may have collected. Since the stagnant water in the well initially was

purged, the water sample consists of only the "fresh" groundwater that has seeped into the well from the surrounding aquifer.

(8) Records of supplemental data from the well water are taken at the beginning of the purge (BOP), at the end of the purge (EOP), as well as from the actual sample. Supplemental data include the water's pH, temperature, and specific conductivity.

(9) The sample is sealed and transported under refrigeration to the lab for further analysis.

An example of a Monitoring Well Sample Data field report by Universal Laboratories is included in Appendix B.

4.3.2 Lab Testing Procedure

Upon receiving the well water samples, Universal Laboratories tests for hardness, total lead concentration, and dissolved lead concentration.

Universal Laboratories determined total and dissolved lead by atomic absorption spectroscopy under EPA method SW846 7421. Total lead was determined from the original sample, while dissolved lead is the concentration found after the sample is filtered through a 0.45 um (micron) filter. Method 7421 uses a graphite furnace that atomizes the sample for 10 seconds at a temperature of 2,700° C. Since a furnace rather than a flame is used to atomize the sample, "a greater percentage of available analyte atoms is vaporized and dissociated for absorption."[64] This enables method 7421 to use smaller sample volumes and to detect lower concentrations of lead in comparison to methods 6010 or 200.7.

A different technique used in the past to test lead concentrations in NAB Little Creek's small arms range monitoring well samples was method 6010, also known as method 200.7. It uses an inductively coupled plasma (ICP) torch to produce "characteristic atomic-line emission spectra" (i.e. light) which is then measured by optical spectrometry.[65] Since methods 6010 and

200.7 are not as sensitive as method 7421 at detecting minute quantities of lead in the water, they were discontinued in NAB Little Creek's groundwater well monitoring program.

Universal Laboratories determines the method detection limit (MDL) for every test that it performs by conducting a Method Detection Limit Study at least annually.[66] Their reference manual defines method detection limit (MDL) as "the minimum concentration that can be measured and reported with 99% confidence that the analyte concentration is greater than zero".[67]

An example of a Monitoring Well Sample Analysis report by Universal Laboratories is included in Appendix B.

Chapter 5
STATISTICAL METHOD OF ANALYSIS

The main objective of statistical analyses was to determine with 95% confidence whether, after implementation of the BMP Plan in the Fall of 1996, a significant change had taken place in the central tendency of the continuous variable population of dissolved lead concentrations in the groundwater at NAB Little Creek's outdoor rifle range. Statistical analyses was necessary to be certain that an observed change was not simply due to random errors or variability. A secondary objective was to determine if any supplemental sample factors correlated with the sample's dissolved lead concentration. These factors included field pH, specific conductivity, temperature, and hardness. The rational was that if such a correlation were found to exist, perhaps it could be used by range managers as a tool to monitor and/or reduce dissolved lead levels in the groundwater without expensive laboratory tests.

5.1 Pearson Correlation Test

A Pearson Correlation test was performed using the pre-BMP implementation data that compared dissolved lead concentration with each of the following factors: 1) distance to the center of the impact berm face; 2) field pH; 3) specific conductivity; 4) temperature; and 5) hardness to determine if there was any correlation between any of these factors and dissolved lead concentration. The Pearson Correlation test was chosen because it is a good measure of linear association between two variables. Values of the correlation coefficient range from -1 to +1 with values closest to zero representing little to no correlation and values nearest -1 or +1 indicating strong relationships between variables. The test also calculates the two-tailed significance of the correlation. If the two-tailed significance is less than or equal 0.05, then there would be a 95% confidence level that there existed a strong correlation between the two variables.

5.2 Wilcoxon Rank-Sum Test

A two-sided small sample test of hypothesis was constructed to test if the BMP implementation project had any effect on dissolved lead concentrations. Originally, the two-sample Student's t test was proposed. However, due to non-normal conditions, the Student's t's non-parametric counterpart, the Wilcoxon Rank-Sum test, had to be used instead. Non-parametric statistics like the Wilcoxon Rank-Sum test are valid for hypotheses testing even if the underlying distributions are quite non-normal.[68] The Wilcoxon Rank-Sum test makes use of ranks, rather than the raw data itself. This test was appropriate because there were only two levels of the nominal variable (i.e. before and after the BMP implementation project). The study's data points met the test's assumption of sample independence because each point was taken from a different water sample.

The two-sided test of hypothesis consisted of a null hypothesis and an alternative hypothesis. The null hypothesis, H_0, was that the BMP project performed in the Fall of 1996 had no treatment effect on the population median of dissolved lead concentrations in the rifle range groundwater. Thus H_0: $\mu_{before} - \mu_{after} = 0$, where μ_{before} was the population mean dissolved lead concentration before and μ_{after} was the population mean dissolved lead concentration after the BMP implementation project. This was to be tested against the alternative hypothesis, H_A, which was that the BMP project performed in the Fall of 1996 did indeed have an effect on the population mean of the dissolved lead concentrations in the rifle range groundwater (H_A: $\mu_{before} - \mu_{after} \neq 0$). If H_0 was rejected, the direction of change (increase or decrease) from μ_{before} to μ_{after} was estimated based on descriptive statistics from the two samples. The test statistic was the Wilcoxon Rank-Sum W. The significance level, α, at which the hypothesis was tested was 0.05. The rejection region of the null hypothesis was defined in two ways.

(1) Either the calculated Wilcoxon Rank-Sum statistic w was $\geq$ c, the upper-tail critical value from the Wilcoxon Rank-Sum statistic tables, or $w \leq m(m + n + 1) - c$, the lower-tail critical value, where the probability $P(W \geq c$ when H_0 is true$) = \alpha/2$.

(2) The computed 2-tailed p-value was $\leq \alpha = 0.05$.

If either one of these two statements were true, the null hypothesis could be rejected with at least 95% certainty that what was found in the samples was true of the underlying populations.

However, prior to performing the Wilcoxon Rank-Sum test on all twenty *before* and *after* data observations, the data had to be analyzed to determine if there were any significant differences between the four rifle range wells that would have prevented an unbiased direct comparison. According to Lehmann, "when the observations are divided into blocks, which presumably vary (i.e. contain random errors and variability) considerably among each other, observations from different blocks are not directly comparable".[69] Due to the small number of samples per well, a statistical test of the *before* and *after* data on a per-well basis would have been meaningless. It was important to use the data from all four wells if the analyses were to have any strength.

5.3 Kruskal-Wallis Test

The Kruskal-Wallis test statistic was chosen to check the variability between the four wells because it is the non-parametric equivalent of the one way ANOVA, or F test.[70] The Kruskal-Wallis test would indicate if there was a statistically significant difference between *any* two of the four wells' mean dissolved lead concentrations. While the assumption of normality is required for validity of the F test, the validity of the Kruskal-Wallis test for testing equality of the well means depends only on the random deviations from the well's true mean having the same distribution.[71] Significance in the Kruskal-Wallis test meant that at least two, possibly more, well means were different. Using the model provided by Montgomery and Runger,[72] the Kruskal-Wallis problem was framed as follows:

> Suppose N (20 in this study) is the total number of observations. All N observations are ranked from smallest to largest. The smallest observation is assigned the rank 1, the next rank 2,..., and the largest rank N, i.e. 20. If the null hypothesis
>
> $$H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 \quad (4 \text{ wells})$$

is true, the N observations come from the same distribution, and all possible assignments of the N ranks to the 4 wells are equally likely, then the ranks 1, 2, ..., N would be expected to be mixed throughout the 4 well blocks. If, however, the null hypothesis H_0 is false, then some wells would consist of observations having predominantly small ranks, while other wells would consist of observations having predominantly large ranks. The Kruskal-Wallis test statistic, H, measures the degree to which the actual observed average ranks differ from their expected value. If this difference is large, then the null hypothesis H_0 is rejected. In other words, the null hypothesis H_0 should be rejected in favor of the alternative hypothesis H_A if the well data generate large values for H. The alternative hypothesis is H_A: at least two of the four well means are different.

Like the Wilcoxon Rank-Sum test, the Kruskal-Wallis test statistic, H, is based on ranks. However, the Kruskal-Wallis test is more appropriate in this case because it can compare the means from more than two independent samples, unlike the Wilcoxon Rank-Sum test. The assumption of independence was met because the observations came from different samples. Since there were four wells and at least five observations from each well, the chi-square "large-sample" approximation of the Kruskal-Wallis test statistic was applicable with three degrees of freedom. The significance level, α, at which the hypothesis was tested was 0.05. The rejection region of the null hypothesis was defined in two ways.

(1) The calculated chi-square approximation of H was $\geq \chi^2_{0.05,\,3}$, the critical value from the chi-square statistic tables.

(2) The computed significance (p-value) was $\leq \alpha = 0.05$.

If either one of these statements were true, the null hypothesis could be rejected with at least 95% certainty that what was found in the samples was true of the underlying populations. In this analysis, accepting the null hypothesis is desired because insignificant differences between wells permit using all twenty data points in the Wilcoxon Rank-Sum analyses rather than only five data points on a per-well basis.

Chapter 6
RESULTS

6.1 Descriptive Statistics for Rifle Range Wells

Table 2, below, summarizes the sample median, mean, and standard deviation of dissolved lead concentrations for each rifle range well.

Table 2: Descriptive Statistics for Rifle Range Wells

Well No.	Sample Mean Dissolved Lead Conc. (ug/L)	Sample Median Dissolved Lead Conc. (ug/L)	Sample Standard Deviation Dissolved Lead Conc. (ug/L)
GW-02	33.30	39.80	24.98
GW-07	38.40	0.59	82.64
GW-08	99.08	87.00	71.08
GW-11	119.98	64.20	109.14

6.2 Correlation of Pre-BMP Implementation Factors

A Pearson Correlation test was performed using the pre-BMP implementation data that compared dissolved lead concentration with each of the following factors: 1) distance to the center of the impact berm face; 2) field pH; 3) specific conductivity; 4) temperature; and 5) hardness to determine if there was any correlation between any of these factors and dissolved lead concentration. The Pearson Correlation test measured the linear association between two variables. Values of the correlation coefficient range from -1 to +1 with values closest to zero representing little to no correlation and values nearest -1 or +1 indicating strong relationships between variables. The test also calculated the two-tailed significance of the correlation. If the two-tailed significance was less than or equal 0.05, then there would be a 95% confidence level

that there existed a strong correlation between the two variables. The computed estimates of correlation coefficients and significance levels are shown in Table 3.

Table 3: Correlation Estimates of Pre-BMP Implementation Factors

Factor	Correlation to Dissolved Lead Concentration	Significance
Distance to the center of the impact berm face	-0.1604	0.619
pH	-0.4520	0.140
Specific conductivity	-0.4345	0.158
Temperature	-0.2256	0.481
Hardness as $CaCO_3$	-0.4682	0.125

6.3 Kruskal-Wallis Test for Variability Between Wells

The Kruskal-Wallis test statistic was used to check variability between the four rifle range wells. Negligible variability between wells was needed before proceeding with the Wilcoxon Rank-Sum test on all twenty of the *before* and *after* BMP implementation data observations. Applying the standard eight-step hypothesis testing procedure to this problem:

1. The parameters of interest were the means of the 4 well distributions of dissolved lead concentration.

2. Null Hypothesis H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$ (4 wells)

3. Alternative Hypothesis H_A: at least two of the four well means were different

4. $\alpha = 0.05$ is the significance level at which the hypothesis was tested.

5. Kruskal-Wallis, H, by the chi-square approximation, was the test statistic.

6. Reject H_0 if either the calculated chi-square approximation of H was $\geq \chi^2_{0.05,3}$, or the computed significance (p-value) was $\leq \alpha = 0.05$. , The critical value, $\chi^2_{0.05,3}$, is = 7.815 from the chi-square statistic tables.

7. Computation results from the computer software program, SPSS® 6.1 for Windows™ Student Version[73], were as follows:

H value (chi-square)	Degrees of freedom	Significance
7.2514	3	0.0643

8. Conclusion: Technically, since the computed chi-square value of 7.2514 was $< \chi^2_{0.05,\,3}$ of 7.815 from the tables, the null hypothesis would not be rejected. However, since the two values were so close to each other, and the computed significance nearly 0.05, substantial variability between wells was indicated. The researcher therefore thought it prudent to align, or "stabilize", the data against this between-well variability prior to proceeding with the Wilcoxon Rank-Sum test.

This variability between wells is shown in Table 2 and graphically in the boxplot of Figure 6. Boxplots are sometimes known as a "box and whiskers" plots because they are formed from "boxes" which contain the 50% of the values falling between the 25th and 75th percentiles, and "whiskers", which are lines that extend from the box to the highest and lowest values, excluding outliers and extremes. A line across the box indicates the sample median. Outliers are cases whose values are between 1.5 and 3 box-lengths from the upper or lower edge of the box. Extremes are cases whose values are more than 3 box-lengths from the upper or lower edge of the box. Boxplots are good at illustrating non-parametric distributions because they are summary plots based on the median and quartiles of the observations, which are resistant to extreme or outlier values. They can also convey information about spread and skewness of the data.[74]

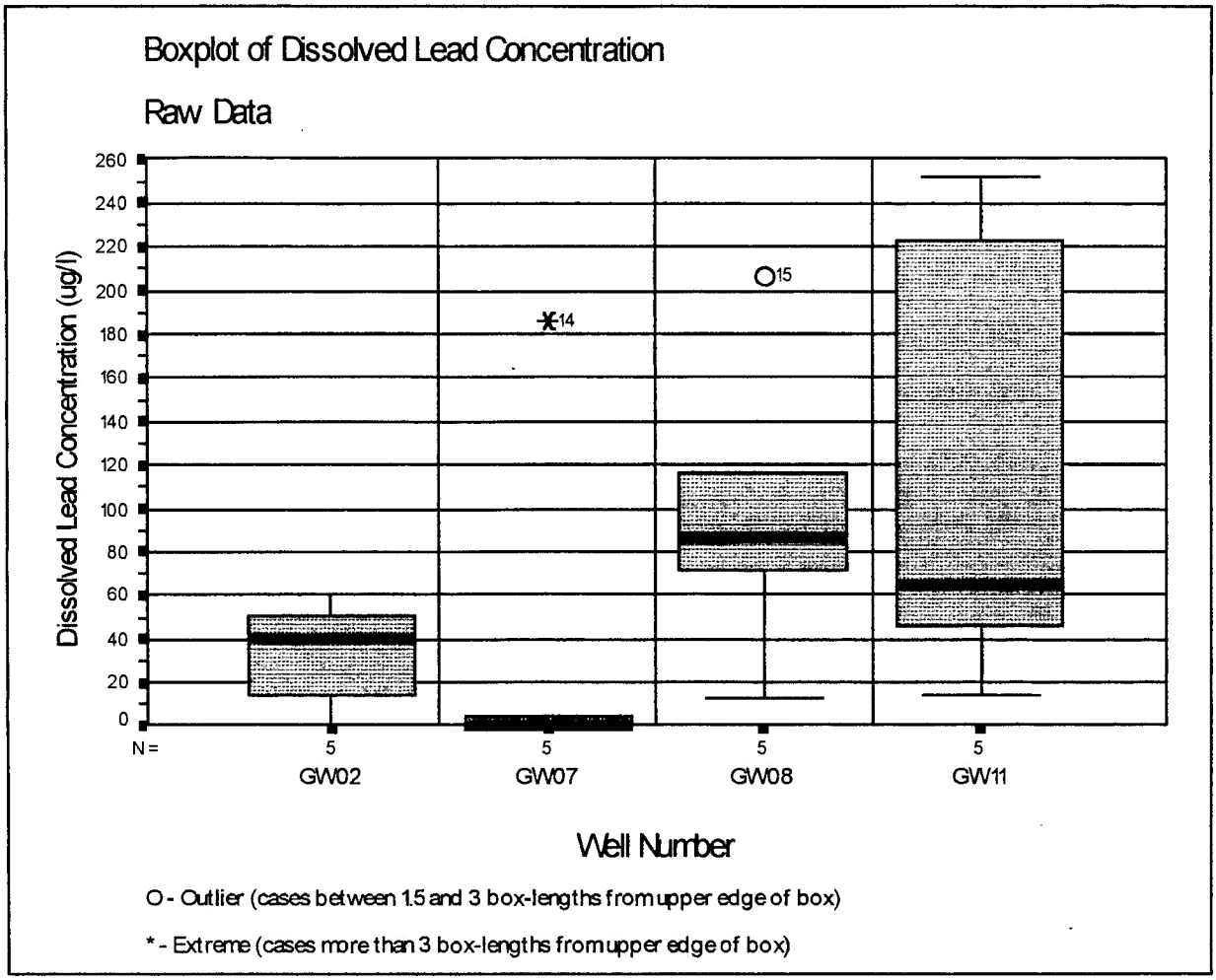


Figure 6: Boxplot of dissolved lead concentration by well using the original (raw) data.

With 94% confidence, it can be stated that the dissolved lead concentrations were not directly comparable since they depended on the well location from which the samples were drawn. Fortunately, Lehmann explains there is a way to eliminate or reduce this variability, with respect to location of central tendency and scale of dispersion, by subtracting from each observation the average of the observations for that well then dividing by the standard deviation for that well.[75] The data was therefore stabilized by first subtracting the well's mean value of dissolved lead from each dissolved lead observation then dividing the difference by the well's standard deviation.

7. Repeating the Kruskal-Wallis test with the stabilized data produced the following computational results:

H value (chi-square)	Degrees of freedom	Significance
0.2571	3	.9679

8. Conclusion: Since the computed chi-square value of 0.2571 was substantially less than $\chi^2_{0.05,3}$ of 7.815, the null hypothesis could not be rejected. However, unlike when the raw data was used, the stabilized data produced results that were far below the chi-square critical value. Since the between-well variability was reduced to the point that it could be ignored, analyses proceeded with the Wilcoxon Rank-Sum test.

The reduction in variability between wells due to data stabilization is shown graphically in the boxplot of Figure 7. The variability has been reduced in terms of both location of central tendency (median) and scale of dispersion (inter-quartile range).

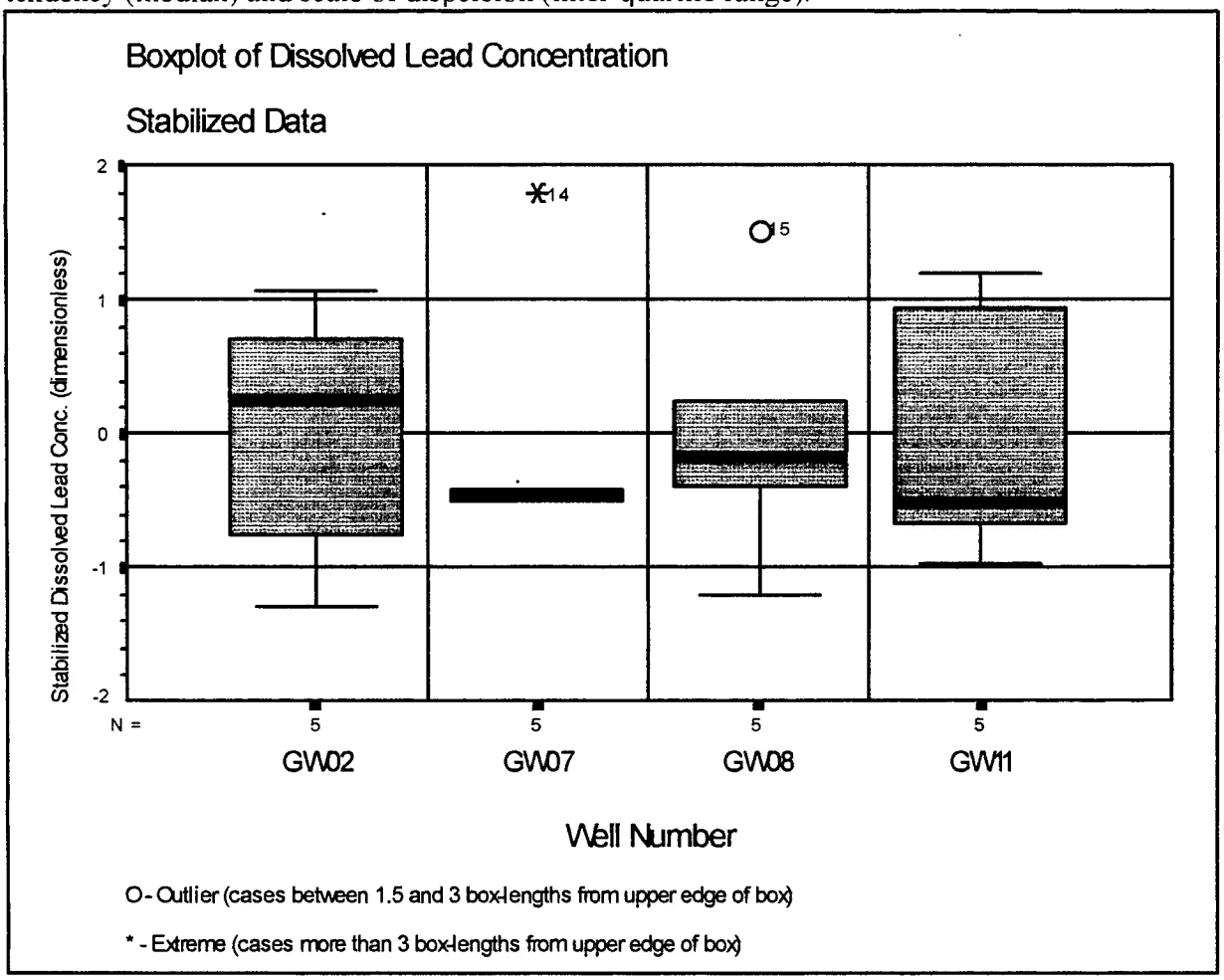


Figure 7: Boxplot of dissolved lead concentration by well using the "stabilized" data.

6.4 Wilcoxon Rank-Sum Test for Comparison of Before and After BMP Implementation

Having sufficiently reduced the variability between well groups through stabilization, the combined observations from all the wells can be used in the analyses. The Wilcoxon Rank-Sum test was used to check if the BMP implementation project had any effect on dissolved lead concentrations. Applying the eight-step hypothesis testing procedure to the "stabilized" data:

1. The parameters of interest were the means of dissolved lead concentration of the two distributions, one *before* and one *after* the BMP implementation project of the Fall of 1996.

2. Null Hypothesis H_0: $\mu_{before} - \mu_{after} = 0$

3. Alternative Hypothesis H_A: $\mu_{before} - \mu_{after} \neq 0$

4. $\alpha = 0.05$ was the significance level at which the hypothesis was tested.

5. Wilcoxon Rank-Sum W was the test statistic.

6. Reject H_0 if either of the following were true:

   (1) Either the calculated Wilcoxon Rank-Sum statistic w is $\geq$ c, the upper-tail critical value from the Wilcoxon Rank-Sum statistic tables, or w is $\leq m(m + n + 1) - c$, the lower-tail critical value, where the probability $P(W \geq c$ when H_0 is true$) = \alpha/2$.

   (2) The computed 2-tailed p-value was $\leq \alpha = 0.05$.

7. Computation results from the computer software program, SPSS® 6.1 for Windows™ Student Version[76], were as follows:

Wilcoxon Rank-Sum W	2-tailed p-value
82	> 0.05

8. Conclusion: Since the computed Wilcoxon Rank-Sum statistic W of 82 was not significant at the 0.05 level (i.e. 2-tailed p-value was not $\leq \alpha = 0.05$), the null hypothesis H_0: $\mu_{before} - \mu_{after} = 0$ cannot be rejected. Based on this test alone, it cannot be concluded that the BMP implementation project performed in the Fall of 1996 had a statistically significant effect on the population mean of the dissolved lead levels in the rifle range groundwater.

However, very different Wilcoxon Rank-Sum test results were obtained when the data was grouped in three blocks: (1) before Fall 1996, (2) April 1997, and (3) July 1997.

When comparing the before Fall 1996 data (block 1) with the 21 April 1997 data (block 2), the Wilcoxon Rank-Sum test calculated a W of 83 and a 2-tailed p-value of < 0.05. Since the computed W was significant at the 0.05 level, the null hypothesis H_0: $\mu_{block\ 1} - \mu_{block\ 2} = 0$ was rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 1} - \mu_{block\ 2} \neq 0$. From descriptive statistics of the block groups, shown in Table 4, the direction of the change was observed to be strongly up from before Fall 1996 to 21 April 1997.

When comparing the 21 April 1997 data (block 2) with the 1 July 1997 data (block 3), the Wilcoxon Rank-Sum test calculated a W of 10 and a 2-tailed p-value of < 0.05. A manual calculation of the Wilcoxon Rank-Sum test, shown in Appendix C, verified the SPSS calculation of W=10 as correct. Since w was ≤ 11 (the lower-tail critical value) and since the computed value for W was significant at the 0.05 level, the null hypothesis H_0: $\mu_{block\ 2} - \mu_{block\ 3} = 0$ was rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 2} - \mu_{block\ 3} \neq 0$. From descriptive statistics of the block groups, shown in Table 4, the direction of the change was observed to be strongly down from 21 April 1997 to 1 July 1997.

When comparing the before Fall 1996 data (block 1) with the 1 July 1997 data (block 3), the Wilcoxon Rank-Sum test calculated a W of 13 and a 2-tailed p-value of < 0.05. Since the computed value for W was significant at the 0.05 level, the null hypothesis H_0: $\mu_{block\ 1} - \mu_{block\ 3} = 0$ was rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 1} - \mu_{block\ 3} \neq 0$. From descriptive statistics of the block groups, shown in Table 4, the direction of the change was observed to be strongly down from before Fall 1996 to 1 July 1997.

6.5 Summary Statistics of Blocked Data (Rifle Range)

Table 4: Descriptive Statistics of the Rifle Range Dissolved Lead Concentrations Grouped in Three Blocks: (1) before Fall 1996, (2) April 1997, and (3) July 1997.

Descriptive Statistic of Dissolved Lead Concentrations	Before the BMP Project of Fall 1996	21 April 1997	1 July 1997
Cases	12	4	4
Sample Mean (ug/L)	64.05	164.00	7.31
Sample Median (ug/L)	55.70	196.70	7.15
Sample Std. Deviation (ug/L)	69.55	84.15	7.74
Range: Minimum to Max (ug/L)	0.50 - 252.00	39.80 - 222.80	0.35 - 14.60

A graphical illustration of data provided in Table 4 is shown in Figure 8.

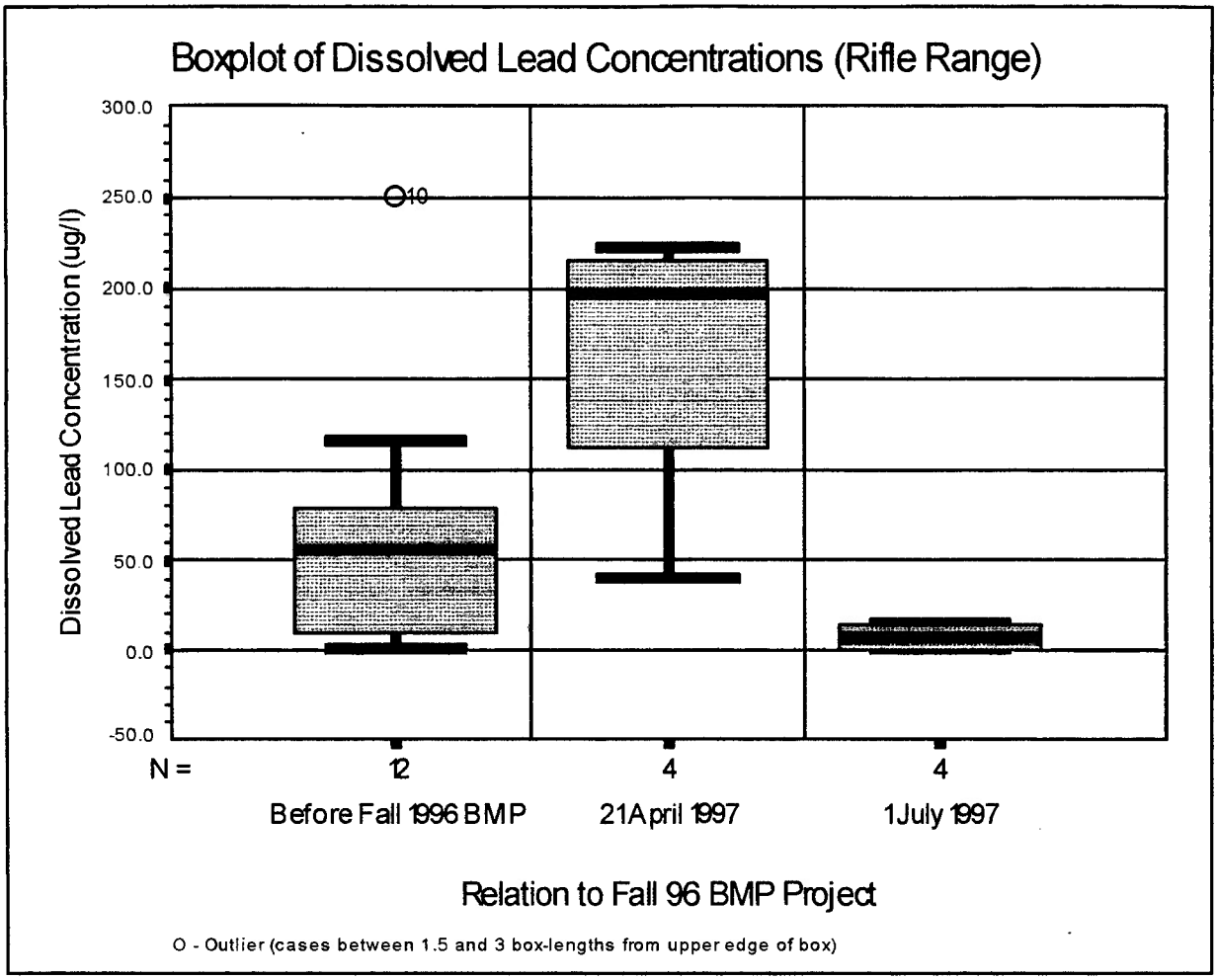


Figure 8: Boxplot of outdoor rifle range dissolved lead concentrations

6.6 Pistol Range Data

Although no BMP implementation project was performed at NAB Little Creek's outdoor pistol range, the researcher though it would be interesting to see what was happening to the groundwater's dissolved lead concentrations where nothing had been done to the soil. In a way, the pistol range could act as a control for the experiment conducted at the rifle range. Therefore, non-parametric statistical analyses identical to that used for the outdoor rifle range was performed on the groundwater samples taken from the outdoor pistol range.

6.6.1 Kruskal-Wallis Test for Variability Between Wells

As was done with the rifle range data, the pistol range data also had to be stabilized by first subtracting the well's mean concentration from the observation, then dividing the difference by the well's standard deviation in order to reduce variability between wells. After stabilization, the Kruskal-Wallis test computed a chi-square approximation of $H = 1.5446$ with significance > 0.05. Since this value is substantially less than the chi-square critical value $\chi^2_{0.05,\,4}$ of 9.488, the null hypothesis could not be rejected. Therefore, the variability between wells had been sufficiently reduced to permit proceeding with the Wilcoxon Rank-Sum test.

6.6.2 Wilcoxon Rank-Sum Test for Comparisons Between Groups

The Wilcoxon Rank-Sum test was performed on pistol range dissolved lead concentrations comparing the samples taken before the Fall of 1996 with the samples taken after the Fall of 1996. Since there are five wells at the pistol range, there are 15 observations in the before group and 10 observations in the after group. Since the number of observations in both groups exceed eight, the distribution W can be approximated by a normal curve. As with the rifle range data, the null hypothesis was H_0: $\mu_{before} - \mu_{after} = 0$. The alternative hypothesis was H_A: $\mu_{before} - \mu_{after} \neq 0$.

$\alpha = 0.05$ was the significance level at which the hypothesis was tested. The computed Wilcoxon Rank-Sum normal approximation test statistic was $Z = -2.1087$ with a two-tailed p-value < 0.05.

Since the computed Z approximation was $< -z_{\alpha/2} = -1.96$ (lower-tailed critical value), the null hypothesis H_0: $\mu_{before} - \mu_{after} = 0$ can be rejected at the 0.05 significance level in favor of the alternative hypothesis H_A: $\mu_{before} - \mu_{after} \neq 0$. From descriptive statistics of the before and after groups, shown in Table 5, the direction of the change in dissolved lead levels at the pistol range was observed to be strongly up from before Fall 1996 to after Fall 1996.

In order to compare trends at the rifle range with that at the pistol range, the Wilcoxon Rank-Sum test was performed on the pistol range data grouped in the same three blocks as had been the data at the rifle range: (1) before Fall 1996, (2) April 1997, and (3) July 1997. Since the number of observations in blocks (2) and (3) did not exceed eight, the normal approximation of the Wilcoxon Rank-Sum test statistic could not be used.

When comparing the before Fall 1996 data (block 1) with the 21 April 1997 data (block 2), the Wilcoxon Rank-Sum test calculated a W of 123 and a 2-tailed p-value of < 0.01. Since the computed W was significant at the 0.01 and the 0.05 level, the null hypothesis H_0: $\mu_{block\ 1} - \mu_{block\ 2} = 0$ was rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 1} - \mu_{block\ 2} \neq 0$. From descriptive statistics of the block groups, shown in Table 5, the direction of the change was observed to be strongly up from before Fall 1996 to 21 April 1997.

When comparing the 21 April 1997 data (block 2) with the 2 July 1997 data (block 3), the Wilcoxon Rank-Sum test calculated a W of 17 and a 2-tailed p-value of < 0.05. Since the computed value for W was significant at the 0.05 level, the null hypothesis H_0: $\mu_{block\ 2} - \mu_{block\ 3} = 0$ was rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 2} - \mu_{block\ 3} \neq 0$. From descriptive statistics of the block groups, shown in Table 5, the direction of the change was observed to be strongly down from 21 April 1997 to 2 July 1997.

When comparing the before Fall 1996 data (block 1) with the 2 July 1997 data (block 3), the Wilcoxon Rank-Sum test calculated a W of 154 and a 2-tailed p-value of > 0.05. Since the computed value for W was not significant at the 0.05 level, the null hypothesis H_0: $\mu_{block\ 1} - \mu_{block\ 3} = 0$ was not rejected in favor of the alternative hypothesis H_A: $\mu_{block\ 1} - \mu_{block\ 3} \neq 0$. From

descriptive statistics of the block groups, shown in Table 5, there was little change in the sample means of the two groups.

6.6.3 Summary Statistics of Blocked Data (Pistol Range)

Table 5: Descriptive Statistics of the Pistol Range Dissolved Lead Concentrations Grouped in Three Blocks: (1) before Fall 1996, (2) April 1997, (3) July 1997, and (4) Combined after Fall 1996.

Descriptive Statistics of Dissolved Lead Concentrations	Before Fall 1996	21 April 1997	2 July 1997	Combined After Fall 1996
Cases	15	5	5	10
Sample Mean (ug/L)	23.11	195.72	19.92	107.82
Sample Median (ug/L)	2.56	74.00	10.70	27.10
Sample Std. Deviation (ug/L)	43.79	222.23	31.00	175.96
Range: Minimum to Max (ug/L)	0.50 - 134.00	6.10 - 511.80	0.35 - 74.30	0.35 - 511.80

A graphical illustration of data provided in Table 5 is shown in Figure 9.

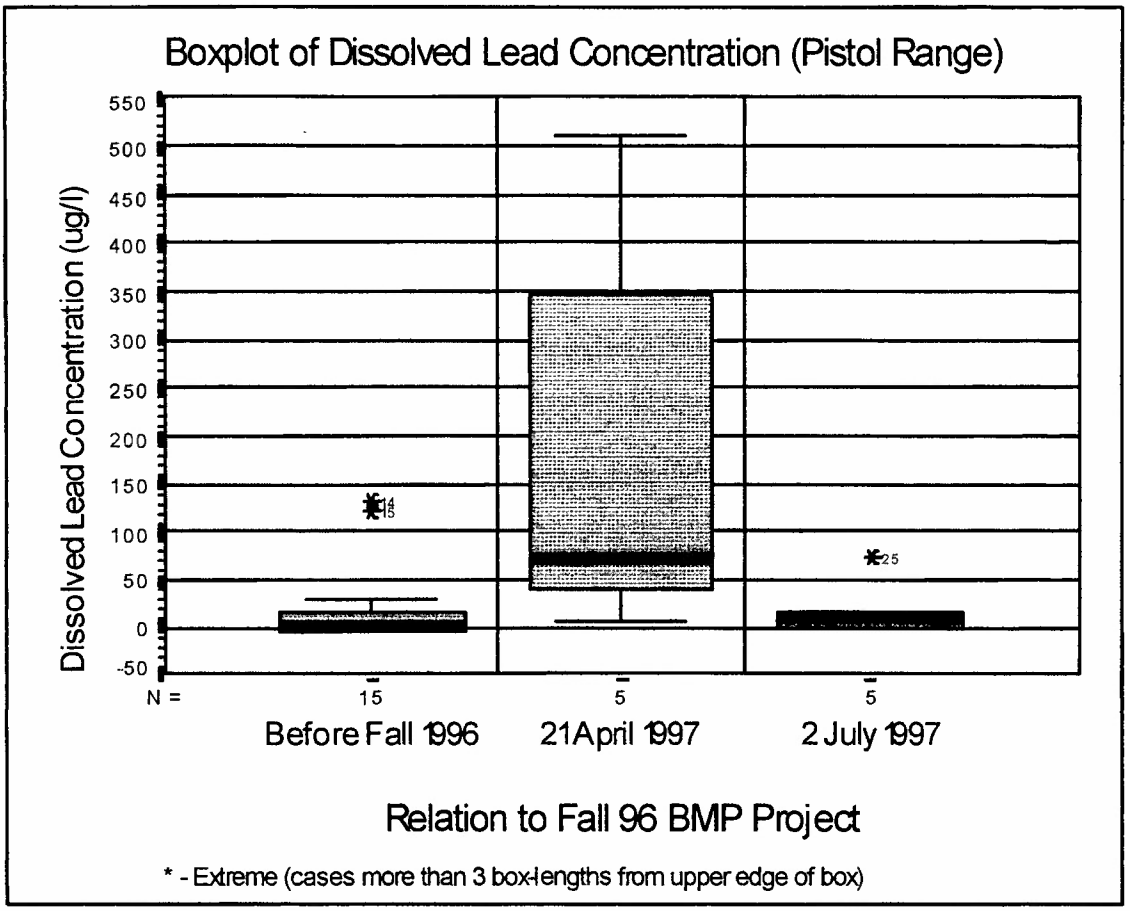


Figure 9: Boxplot of outdoor pistol range dissolved lead concentrations

Chapter 7
DISCUSSION

7.1 Correlation of Pre-BMP Implementation Factors

As shown in Table 2 at the beginning of the previous chapter, a Pearson Correlation test on the pre-BMP implementation data did not show a good correlation between dissolved lead concentration and any of the following factors: 1) distance to the center of the impact berm face, 2) field pH, 3) specific conductivity, 4) temperature, and 5) hardness. Since none of the computed correlation coefficients were significant at the 0.05 level, the conclusion is that there is not a statistically significant (95% confidence level) correlation between dissolved lead concentration and any of the listed supplemental factors. If there had been a strong correlation, it might have been useful as a means of indirectly tracking dissolved lead levels without expensive laboratory tests.

7.2 Effectiveness of the BMP Implementation Project

7.2.1 Evidence of a Change in Dissolved Lead Concentrations

Although the Wilcoxon Rank-Sum test comparing the two samples of dissolved lead concentrations before and after the Fall 1996 BMP implementation project was inconclusive, much can still be learned from the results. When the after data was separated into the 21 April 1997 group and the 1 July 1997 group, direct comparisons between groups became statistically significant. As shown in Figure 8, the dissolved lead concentrations at the rifle range went up quite a bit from before Fall 1996 to April 1997. The dissolved lead levels then went down a lot from April 1997 to July 1997. As shown in Figure 9, the outdoor pistol range experienced a similar up-down trend from before Fall 1996 to July 1997. However, the pistol range's dissolved lead concentrations appeared to return to approximately the same levels in July 1997 that it had experienced prior to Fall 1996. On the other hand, during that same period (April to July 1997)

the rifle range's dissolved lead levels dropped to below what they had been before Fall 1996. In fact, this drop in dissolved lead concentrations was statistically significant at the 0.05 level. The April 1997 data appears to have been a temporary fluke increase since the same temporary rise in dissolved lead concentrations was observed in both the rifle and the pistol range observations. However, without additional sample observations, it would be premature to pass judgment on the effectiveness of the BMP Plan at the rifle range.

7.2.2 Theories to Explain the Changes in Dissolved Lead Concentrations

Since no BMP Implementation took place at the pistol range, the observed increase in dissolved lead levels at both the rifle and pistol ranges in April 1997 must be due to some other reasons. What do the rifle and pistol ranges have in common? They share a common groundwater aquifer. They are both geographically situated between freshwater lakes and the Chesapeake Bay. And they both share the same weather. Perhaps dissolved lead concentrations in the groundwater are affected by changes in the water table. The water table dropped on average almost half a foot between 21 April 1997 and 1 and 2 July 1997. Since the laboratory field technicians measure the static "depth to water level" every time they take samples, this data can be used to track the depth of the water table at both ranges. An example of such water table information is found in Appendix D.

There is the possibility that the change in laboratories performing the tests could have been a factor. However, this point is mitigated since both laboratories followed the same EPA method 7421 protocols for analyzing the dissolved lead concentrations, and each had similar method detection limits. As additional rounds of groundwater well samples are drawn from the rifle range, perhaps trends will appear in the data.

Finally, there is always the possibility that the lead found in the groundwater beneath the rifle range is not from the range. Barnes et al., stated in their report that "it is also possible that there is a contributing source not related to either firing range".[77] Since no groundwater modeling has been performed, the rate or direction of groundwater flow beneath the small arms

range is unknown. If such information were known, then additional groundwater sampling wells should be installed up-gradient from the rifle and pistol ranges. That would really be the only way to determine what was really going on in the groundwater at the site.

7.3 Additional Observations

From the specific conductivity levels shown in Table 1, well GW-07 shows evidence of saltwater intrusion from tidal influence. This makes sense since well GW-07 is located on the backside of the rifle range berm on Salerno Beach, and hence is only a few feet away from the Chesapeake Bay, as seen in Figure 4. Consequently, since the waters of the Chesapeake Bay are close to pH neutral, this explains why the pH levels of well GW-07, with a mean pH of 6.52, are closer to neutral than the other wells, which have a combined mean pH of 5.23. Thus it is not unexpected that well GW-07 has the lowest median dissolved lead concentration of any of the wells, as seen in Figure 6.

Chapter 8
CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

1. As discussed in Chapter 2, the BMPs appear to be based on sound science. But while that science has been demonstrated in the laboratory, there are few field studies documenting the effectiveness of BMPs at small arms ranges. That is why it is important to continue monitoring, experimenting, and learning about what works and what doesn't. There are still too many variables as yet unaccounted for in the model.

2. Periodic recovery and recycling of lead bullets makes sense to reduce the source of lead contamination from the berm and to prevent ricochet. However, six inches may not be deep enough to recover rifle bullets that can be expected to penetrate deeper than that.

3. Unless a more efficient method of recovery is used, material removed from the impact berm by the sieve cannot be expected to contain sufficient total lead content to permit recycling. Failing to recognize this can result in costly, unforeseen expenditures for hazardous waste disposal.

4. There is no strong correlation between dissolved lead concentration and any of the following supplemental factors: 1) distance to the center of the impact berm face; 2) field pH; 3) specific conductivity; 4) temperature; and 5) hardness.

5. If more frequent sampling was performed, say monthly rather than quarterly, enough data could be compiled to determine the seasonal variation in dissolved lead concentrations. Additional sampling would also add strength to statistical analysis, since there are so few

monitoring wells at each range. Quarterly sampling does not provide enough sample per year to account for seasonal variation and/or changes in water table depth.

8.2 Recommendations

1. Change the frequency of groundwater monitoring well sampling from quarterly to monthly. The additional samples should enable one to factor out the normal seasonal fluctuations out of the picture in order to determine if the BMPs really did make a difference.

2. Find out to what depth most rifle bullets will penetrate into the impact berm. Then excavate beyond that depth to ensure retrieval of the majority of lead in the berm.

3. Future BMPs should be quantifiable for each specific site. Implementation should be targeted to those measurable quantities. Maintaining soil pH within a specific range is one example.

4. Scientific research and field verification of BMPs should be conducted to definitively determine their impacts.

5. Since the soil that passes through the sieve may still be contaminated with lead, it should be tested to determine the extent of its lead contamination. If the leachable lead content exceeds a certain specified threshold, it may be better to dispose of the contaminated soil as hazardous waste, rather than return it to the rifle range where it would again become a potential source of environmental contamination.

6. It is recommended that the next time soil is excavated for recovery and recycling, a more efficient process of separating the lead from the non-lead debris be used, such as the Pneumatic Separation Unit invented by MARCOR Environmental. This would ensure that the lead material

sent for recycling will have sufficient lead content to permit recycling. Otherwise, NAB Little Creek should plan and budget for disposing of any future material removed from the impact berm as hazardous waste.

7. Test soil pH before, during, and after adding lime to the soil to ensure that enough lime has been added to raise and maintain the soil pH in a range from 6.1 to 6.9, as recommended by Barnes et al. (1996).[78]

8. When phosphorus is added to the berm, it should be pure phosphorus rather than a commercial fertilizer that also contains nitrates. Whatever the source or form of phosphorus, care must be exercised to prevent phosphorus from escaping the range into adjacent waters because resultant blooms of algae could adversely affect water quality. Phosphorus should therefore be used sparingly.

9. Prior to adding organic material, such as leaf and tree mulch, to the soil, the pH of the organic material should be determined. If it is found to be acidic, lime should be added to it until it is in the desired pH range.

10. Detailed groundwater modeling should be performed in and around the outdoor rifle and pistol ranges. Install additional groundwater monitoring wells up-gradient from both the rifle and the pistol ranges. This action would determine what, if any, dissolved lead is coming into the ranges from sources other than expended bullets. In the interim, use the data already collected by the laboratory field technicians, like Appendix D, to develop a water table surface contour map. Such a map may provide a rudimentary groundwater model until a more detailed one can be developed.

Appendix A

Naval Amphibious Base (NAB) Little Creek
Outdoor Small Arms Ranges Groundwater Well Data

Appendix A follows this page.

NAB Little Creek Rifle and Pistol Ranges Groundwater Monitoring Well Sampling Results			Rifle Range			
			GW-02			
				Field	Field	Hardness
			Field Ph	Spec. Cond.	Temp	as CaCO3
Date	Contractor	Method Detection Limits (MDL) for Lead		(umhos/cm)	(deg. C)	(mg/l)
3/30/94	Environmental Testing Svcs, Inc.	Method 6010 Total Lead MDL=20 ug/l, Dissolved MDL=20 ug/l	4.56	132	13.6	284
6/28/94	Environmental Testing Svcs, Inc.	Method 200.7 Total Lead MDL=16 ug/l, Dissolved MDL=16 ug/l	4.44	140	21.4	23
9/29/94	Environmental Testing Svcs, Inc.	Method 7421 Total Lead MDL=1 ug/l, Dissolved MDL=1 ug/l	5.11	95	21.5	95
12/20/94	Environmental Testing Svcs, Inc.	Method 200.7 Total Lead MDL=16 ug/l, Dissolved MDL=18 ug/l	5.20	50	14.92	20
3/22/95	Environmental Testing Svcs, Inc.	Method 7421 Total Lead MDL=1.57 ug/l, Dissolved MDL=1 ug/l	4.43	50	14.6	28
4/25/95	Environmental Testing Svcs, Inc.	Method 7421 Total Lead MDL=1 ug/l, Dissolved MDL=1 ug/l				
6/16/95	Environmental Testing Svcs, Inc.	Method 7421 Lead Total MDL=1.17 ug/l, Dissolved MDL=1 ug/l	4.67	239	21.12	24
9/26/95	Environmental Testing Svcs, Inc.	Method 7421 for Total and Dissolved Lead, 1.17 ug/l MDL	4.77	105	23	12
4/30/96	Environmental Testing Svcs, Inc.	Method 7421 for Total and Dissolved Lead, 1.17 ug/l MDL				40
10/22/96	OHM Remediation Svcs Corp.	Method 6010A SW-846 for ME40 Specific Total & Filtered Lead				
		14 ug/l Detection Limits. Samples drawn from 10/22 - 11/21 1996.				
1/17/97	Universal Laboratories	Method SW846 6010 for Total and Dissolved Lead	5.07	30	9	20
		Method Detection Limits (MDL) = 50 ug/l.				
4/21/97	Universal Laboratories	Method SW846 7421 for Total & Dissolved Lead, 0.7 ug/l MDL	4.80	60	14.9	9
		Method Detection Limits (MDL) = 0.7 ug/l.				
7/1&2/97	Universal Laboratories	Method 7421 for Total and Dissolved Lead, 0.7 ug/l MDL	4.45	45	22.4	10
Note: (1) EPA Method 6010A SW-846 tests for lead using Inductively Coupled Plasma-Atomic Emmision Spectroscopy.						
Note: (2) EPA Method 200.7 is the same as EPA Method 6010.						
Note: (3) EPA Method SW846 7421 tests for lead using Graphite Furnace Atomic Absorption.						
Note: (4) BDL means Below method Detection Limit.						

		Rifle Range						Rifle Range				
						Det. limit	Det. limit					Det. limit
		GW-07				varies	varies	GW-08				varies
Dissolved	Total		Field	Field	Hardness	Dissolved	Total		Field	Field	Hardness	Dissolved
Lead	Lead	Field Ph	Spec. Cond.	Temp	as CaCO3	Lead	Lead	Field Ph	Spec. Cond.	Temp	as CaCO3	Lead
(ug/l)	(ug/l)		(umhos/cm)	(deg. C)	(mg/l)	(ug/l)	(ug/l)		(umhos/cm)	(deg. C)	(mg/l)	(ug/l)
809	998	7.18	200	13.3	292	41	31	6.13	241	12.6	60	490
48	251	6.24	2900	20.9	284	74	BDL	4.63	120	25.4	28	77
387	315	6.06	2200	22.2	220	72.2	65.3	5.39	120	21.1	52	143
30	218	6.25	1600	16.3	4350	BDL	71	5.65	60	14.6	60	155
51	74.1	6.77	1700	13.9	530	BDL	6.8	5.4	60	19.9	44	87
14.4	48.7	6.2	20500	17.86	2040	4.38	10.8	5.43	246	20.85	64	71.8
60.4	130	6.58	17500	23	1690	BDL	8.08	5.8	197	22	60	116
32	85				200	26	27				120	550
1110	1110					216	168					1250
BDL	140	6.41	6500	13.6	765	BDL	BDL	5.74	50	10.6	150	BDL
39.8	54.4	6.54	14200	14.2	2350	186.2	194	5.36	63	15	25	207.2
0.9	18	6.79	7000	20.7	1233	BDL	62.5	5.36	75	21.2	20	13.4

APPENDIX A: NAB LITTLE CREEK OUTDOOR SMALL ARMS RANGES GROUNDWATER WELL DATA THROUGH 2 JULY 1997

	Rifle Range						Rifle Range				Pistol Range	
Det. limit					Det. limit	Det. limit	Field Blank or		Det. limit	Det. limit		
varies	GW-11				varies	varies	Equip. Blank		varies	varies	GW-05	
Total		Field	Field	Hardness	Dissolved	Total		Hardness	Dissolved	Total		Field
Lead	Field Ph	Spec. Cond.	Temp	as CaCO3	Lead	Lead	Field Ph	as CaCO3	Lead	Lead	Field Ph	Spec. Cond.
(ug/l)		(umhos/cm)	(deg. C)	(mg/l)	(ug/l)	(ug/l)		(mg/l)	(ug/l)	(ug/l)		(umhos/cm)
431	4.84	192	12.8	36	506	496		BDL	22	26	5.56	120
105	4.99	230	18.6	204	19	248		BDL	BDL	BDL	4.64	150
129	4.71	80	21.2	315	1820	994		BDL	BDL	BDL	4.6	100
1110	5.67	90	16.1	50	2500	7340		8	BDL	19	5.66	150
153	4.76	85	14.8	40	252	707		BDL	BDL	BDL		
											4.78	478
220	5.29	194	20.32	48	64.2	479		8	2.23	BDL	4.4	216
233	6.18	325	22	80	46.3	102		BDL	BDL	BDL	4.8	120
650				100	1550	2070		BDL	BDL	BDL		
1700					751	3250			19	20		
1560	6.08	95	10.4	50	BDL	6130			BDL	BDL	4.98	90
332	5.84	78	15.2	28	222.8	418			BDL	0.9	4.79	93
191.8	5.7	130	19.8	32	14.6	2189.6					6.7	105

				Pistol Range						Pistol Range		
		Det. limit varies	Det. limit varies	GW-06				Det. limit varies	Det. limit varies	GW-10		
Field Temp (deg. C)	Hardness as CaCO3 (mg/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Field Ph	Field Spec. Cond. (umhos/cm)	Field Temp (deg. C)	Hardness as CaCO3 (mg/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Field Ph	Field Spec. Cond. (umhos/cm)	Field Temp (deg. C)
12.9	28	BDL	32	5.58	100	11.3	60	50	184	3.97	102	12.9
24.4	20	30	31	6.52	130	21.5	40	229	37	4.71	140	17.2
21.4	162	311	278	5.49	110	22.6	100	73.7	65.4	5	105	19.1
13.7	32	40	109	5.32	140	16.6	52	22	208	5.96	120	13.9
18.2	40	10.7	35.1	5.28	222	16.8	56	BDL	12.2	5.2	305	17.5
22.42	68	10.1	46.3	5.12	241	21.64	56	BDL	54.4	4.7	283	17.42
22.5	40	25	96.8	5.61	228	24.5	68	6.33	297	4.83	205	20
	24	120	170				80	110	140			
		185	223					224	277			
8	30	BDL	60	5.92	55	10.6	30	BDL	150	4.48	110	13.1
14.6	8	346.4	405	5.15	90	14.9	32	511.8	726	4.28	82	14.7
21.6	14	13.9	1457.3	5.51	120	21.8	34	BDL	418.2	5.58	115	17

			Pistol Range						Pistol Range			
	Det. limit	Det. limit					Det. limit	Det. limit				
	varies	varies	GW-12				varies	varies	GW-13			
Hardness	Dissolved	Total		Field	Field	Hardness	Dissolved	Total		Field	Field	Hardness
as CaCO3	Lead	Lead	Field Ph	Spec. Cond.	Temp	as CaCO3	Lead	Lead	Field Ph	Spec. Cond.	Temp	as CaCO3
(mg/l)	(ug/l)	(ug/l)		(umhos/cm)	(deg. C)	(mg/l)	(ug/l)	(ug/l)		(umhos/cm)	(deg. C)	(mg/l)
130	BDL	31	4.12	96	14.3	36	BDL	29	5.18	62	14.3	48
108	BDL	57	4.22	380	20.2	118	BDL	28	6.13	140	20.4	75
147	12.8	10.7	4.97	150	21.7	203	17	14.5	6.06	185	19.7	148
24	BDL	42	6.14	115	14.2	140	BDL	29	6.18	98	14.9	56
100	BDL	12.8	4.95	201	16.4	24	1.39	1.45	5.9	279	17.8	88
60	BDL	26.8	4.23	286	20.57	40	BDL	25.4	5.85	299	20.39	96
100	2.56	28.8	5.24	145	22	50	1.4	22.5	6.4	195	20.5	140
170	25	27				180	15	18				72
	58	45					109	52				
20	BDL	BDL	5.03	95	13.2	BDL	BDL	220	6.26	140	12.8	80
10	6.1	8	4.16	178	15.2	15	40.3	61.4	5.73	135	16.5	58
12	BDL	4.4	5.69	250	20.2	26	10.7	142.2	7.37	135	19.3	66

		Pistol Range			Pistol Range			
Det. limit	Det. limit		Det. limit	Det. limit	Field Blank or		Det. limit	Det. limit
varies	varies	GW-13 dup	varies	varies	Equip. Blank		varies	varies
Dissolved	Total		Dissolved	Total		Hardness	Dissolved	Total
Lead	Lead	Field Ph	Lead	Lead	Field Ph	as CaCO3	Lead	Lead
(ug/l)	(ug/l)		(ug/l)	(ug/l)		(mg/l)	(ug/l)	(ug/l)
196	654					BDL	BDL	32
46	761					BDL	BDL	BDL
482	441					BDL	BDL	BDL
310	6690					BDL	BDL	19
29.6	289					BDL	BDL	BDL
134	4680					8	2.23	BDL
123	1960					BDL	BDL	BDL
1220	1330					BDL	BDL	BDL
2540	1960		1810	1800			19	20
BDL	760						BDL	BDL
74	140						BDL	0.9
74.3	1357.2					BDL	BDL	BDL

Appendix B

UNIVERSAL LABORATORIES' MONITORING WELL SAMPLE FIELD AND ANALYSIS REPORTS

Appendix B follows this page.

MONITORING WELL SAMPLE DATA

E-LOCATION: Little Creek WELL ID: GW06

CONTRACT: _____ FREQUENCY: QHY DATE: 1-17-97

WELL CONDITION: locked ___ capped ✓ NOTES: _____
unlocked ✓ uncapped ___

WELL DESCRIPTION: Diam.- 2 inch material- PVC

WATER LEVEL MEASUREMENT DEVICE: SOLNIST SN 13[illegible]749

FIELD ANALYSIS METERS: pH Meter- Beckman SN 218455

Cond. Meter- YSI 33 SN A9017053

Other- _____ SN _____

METHOD OF PURGING: Bailer

METHOD OF SAMPLING: Bailer

Time of Initial Water Level Measurements: 14:28

Depth To Water Level (DWL): 5.35 ft. Total Well Depth (TWD): 11.90 ft.

Depth To Water Level (DWL) at BOP: _____ ft. (USE THIS DWL FOR PURGE VOL. CALC)

Water Column Length (WCL) = (TWD) - (DWL) = 6.55 ft.

Purge Volume = (WCL) x (conv. factor) x (3)

= 6.55 x a|#7 x (3)

= 3.3 Gal.

CONVERSION FACTORS well diam.	fact
2.0 in.	0.17
4.0 in.	0.66

Start Time of Purge: 14.30 End Time of Purge: 14:34

Volume Purged = 3.5 Gal. Well Yield: (HIGH) / LOW

Well Recovery: SLOW / (FAST)

TIME	ACT.	DWL (ft.)	pH	Temp (oC)	SpCond (umhos/cm)	OBSERVATIONS turb	odor	NOTE #	INIT
14:30	BOP	5.35	6.44	10.6	60	3	2		FRSTK
14:34	EOP	5.50	5.99	10.6	55	3	2		FRSTK
14:35	SAM	5.50	5.92	10.6	55	3	2		FRSTK

BOP- Beginning of Purge
EOP- End of Purge
SAM- Sample

Turbidity (turb): 1= clear 2= light 3= moderate 4= dark

Odor: 1= none 2= faint 3= moderate 4= strong

NOTES: _____

UNIVERSAL LABORATORIES

REPORT OF ANALYSIS

20 RESEARCH DRIVE
HAMPTON, VIRGINIA 23666

TELEPHONE: (757) 865-0880
FAX: (757) 865-8014
TOLL FREE: 800-695-2162

TO:

TOM SHAFER
OIC FACILITIES CONTRACTS CODE N461
PWC LITTLE CREEK 1450 GATOR BLVD, STE200
NORFOLK, VA 23521-2619

02/03/97
(Original Report Date)

Clnt Sample ID: GW-02
Location: QUARTERLY WELLS
Matrix: GROUNDWATER
Grab Sample By : SEAN DADSON

Rec by lab: 01/17/97

Log No: 97DD462
W/O No: 97DDD45
Sample Type: Grab
Grab Time: 01/17/97 1648
Composite Time:
from: N/A
to: N/A

TEST	METHOD	SAMP TYPE	TEST RESULTS		DETECTION LIMIT	REG. LIMIT	ANALYSIS DATE TIME	ANLS INIT	EXTRACTION DATE	EXTRACTION TIME
FIELD pH	EPA 150.1/9040	GRAB	5.07		0		01/17/97 1648	SD	N/A	N/A
FIELD SPECIFIC CONDUCTIVITY	SM 2510 B	GRAB	30	umhos/cm	0		01/17/97 1648	SD	N/A	N/A
FIELD TEMPERATURE	SM 2550 B	GRAB	9.0	oC	0		01/17/97 1648	SD	N/A	N/A
HARDNESS as CaCO3- EDTA	SM 2340 C	GRAB	20	mg/l	2		D1/21/97 10DD	DR	N/A	N/A
DISSOLVED LEAD	SW846 6010	GRAB	< D.05	mg/l	D.D5		01/2D/97 150D	SB	N/A	N/A
TOTAL LEAD	SW846 6010	GRAB	0.14	mg/l	0.05		01/2D/97 1500	SB	N/A	N/A

cc: FAX ROA

RESPECTFULLY SUBMITTED,

Appendix C

MANUAL CALCULATION OF WILCOXON RANK-SUM TEST

1. The parameters of interest are the means of dissolved lead concentration of the following two distributions:

Group	Number in Group	Dissolved Lead Concentrations (ug/L)
21 April 1997 (group 1)	m = 4	39.80, 186.20, 207.20, 222.80
1 July 1997 (group 2)	n = 4	0.90, 0.35, 13.40, 14.60

2. Null Hypothesis H_0: $\mu_{before} - \mu_{after} = 0$

3. Alternative Hypothesis H_A: $\mu_{before} - \mu_{after} \neq 0$ (two-tailed test required)

4. $\alpha = 0.05$ is the significance level at which the hypothesis was tested. Since it is a two-tailed test, the α level of 0.05 is divided in half for each tail, i.e. 0.025.

5. Wilcoxon Rank-Sum W is the test statistic.

w_1 = sum of ranks in combined sample associated with observations in group 1.

w_2 = sum of ranks in combined sample associated with observations in group 2.

w_1 and w_2 are related by the equation: $w_2 = [[(n + m)(n + m + 1)] / 2] - w_1$.

6. Reject H_0 if the following is true: Either the calculated Wilcoxon Rank-Sum statistic w is $\geq$ c, the upper-tail critical value from the Wilcoxon Rank-Sum tables, or w is $\leq m(m + n + 1) - c$, the lower-tail critical value, where the probability $P(W \geq c$ when H_0 is true$) = \alpha/2$.

Entering the Wilcoxon Rank-Sum statistical tables with m = 4 and n = 4,[79]

$P(w \geq 25$ when H_0 is true$) = 0.029 \approx 0.025 = \alpha/2 = (0.05)/2$

c = 25 is the upper tail critical value. The critical value for the lower tail is: $m(m + n + 1) - c = 4(4 + 4 + 1) - 25 = 11$. Thus, the rejection region is: H_0 will be rejected if either $w \geq 25$ or $w \leq 11$.

7. Calculation: The two samples are combined and ordered as shown:

Group:	2	2	2	2	1	1	1	1
Dissolved Lead Conc. (ug/L):	0.35	0.90	13.40	14.60	39.80	186.20	207.20	222.80
Rank:	1	2	3	4	5	6	7	8

$w_1 = 1 + 2 + 3 + 4 = 10$, $w_2 = 5 + 6 + 7 + 8 = 26$

8. Conclusion: Since the calculated $w_1 = 10$ is ≤ 11 (lower-tail critical value) and $w_2 = 26$ is ≥ 25 (upper-tail critical value), the null hypothesis H_0: $\mu_{before} - \mu_{after} = 0$ can be rejected in favor of the alternative hypothesis H_A: $\mu_{before} - \mu_{after} \neq 0$. Therefore, it can be concluded that there is a statistically significant (≥95% confidence level) change between the 21 April 1997 dissolved lead concentrations and the 1 July 1997 dissolved lead concentrations in the rifle range groundwater.

Appendix D

NAB LITTLE CREEK WATER TABLE INFORMATION

Range	Well No.	Total Well Depth (ft)	Top of Casing Elevation (ft)	Static Depth to Water 4/21/97 (ft)	Static Depth to Water 7/1&2/97 (ft)	Elevation of Water Table 4/21/97 (ft)	Elevation of Water Table 7/1&2/97 (ft)	Change in Water Table Elevation from 4/21/97 to 7/1&2/97 (ft)
Rifle	GW02	12.92	8.32	5.25	5.61	3.07	2.71	-0.36
	GW07	20.40	14.04	12.45	11.65	1.59	2.39	0.80
	GW08	12.80	8.70	6.75	6.81	1.95	1.89	-0.06
	GW11	14.16	9.81	8.00	8.22	1.81	1.59	-0.22
Pistol	GW05	13.83	9.70	4.45	5.85	5.25	3.85	-1.40
	GW06	11.91	9.40	5.35	6.83	4.05	2.57	-1.48
	GW10	12.28	13.58	9.59	10.35	3.99	3.23	-0.76
	GW12	15.17	13.08	9.58	10.15	3.50	2.93	-0.57
	GW13	10.36	6.59	3.20	3.43	3.39	3.16	-0.23
Both	Total:	123.83	93.22	64.62	68.90	28.60	24.32	-4.28
	Average:	13.76	10.36	7.18	7.66	3.18	2.70	-0.48

Note: (1) Elevations are in feet and are referenced to Virginia Beach Vertical Datum (NGVD 29).
(2) Static Depth to Water is measured from the top of the well casing prior to purging.
(3) Since Well No. GW07 is on the beach of the Chesapeake Bay, it is influenced by the tides.

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